A MANUAL

OF

HYGIENE, SANITATION

AND

SANITARY ENGINEERING

WITH SPECIAL REFERENCES TO INDIAN CONDITIONS.

COMPILED FOR THE USE OF DISTRICT AND MUNICIPAL BOARDS AND THEIR OFFICERS

BY

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EVERY LAW OF NATURE IS THE READY SERVANT OF MANKIND, BENEFICENT WHEN RIGHTLY EMPLOYED, BUT DESTRUCTIVE WHEN NEGLECTED.

Madras:
PRINTED AND PUBLISHED BY THE SUPERINTENDENT, GOVERNMENT PRESS.

1896.

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PREFACE.

THIS volume is the result of an attempt to revise the author's Manual for District and Municipal Boards, a manual, which has, for some years, been out of print; early in the attempt it was realized that something beyond mere revision was desirable; so much more information on sanitary matters was available, so much more knowledge had been gained, that it was decided not only to revise, but to re-arrange the whole work. Some chapters have been re-written from beginning to end; some partially so, but none remain without revision and much fresh matter added to them.

The work, as it now stands, appeals, perhaps, to a wider range of readers, than it could, in its original form, have pretended to reach; hence its altered title. While still suitable for those engaged non-professionally in Local and Municipal government, it will be found that it contains a class of information which, it is trusted, will render it more acceptable to the author's professional brethren, and perhaps also to those officers of the medical profession, whose duties include the sanitary care of districts and towns, many of whom, no doubt, have felt the want of a work devoted entirely to those subjects in which engineering and sanitary knowledge form a necessary combination.

The preparation of the volume has been a labour of love; if it assists those indicated above, even to a small extent, in the execution of their duties, the author will feel that his effort has not been in vain. The volume has, no doubt, many imperfections, but it is hoped that these are not such as will prevent its sanitary mission being in some small measure fulfilled.

The author is indebted to the Government of Madras for the publication of the work, to the Superintendent of the Government Press for the excellence of the printing, and to the Madras Survey Department for the preparation of the many plates and diagrams illustrating the letter-press.

To name all those who have kindly assisted and advised in the preparation of the work for the press would require many pages, and while, therefore, grateful to all, the author would merely particularise his staff, who have given much of their own time to copying and preparing plates and diagrams, Mr. Hormusji Nowroji, A.M.I.C.E., B.C.E., who has kindly revised Chapter VI, Surgeon-Major Thompson, M.B., C.M., who has revised the Chapter on Vaccination, of which he was the author, and Messrs. Simpson and Company, London, Messrs. Richardson and Cruddas, Bombay, and Messrs. Burn and Company, Calcutta, who have furnished those drawings on which their names appear.

J. A. JONES.

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EXPLANATION OF ALGEBRAICAL SIGNS.

The sign of equality is $=$
The sign of addition is $+$
Thus :

$$5 + 4 = 9.$$

The sign of subtraction is $-$
Thus :

$$5 - 4 = 1.$$

The sign of multiplication is $\times$
Thus :

$$5 \times 4 = 20.$$

The sign of division is $\div$
Thus :

$$20 \div 4 \text{ or } \tfrac{20}{4} = 5.$$

An expression, such as $(8 + 1)\ (3 + 2)$ means that the total of the quantities within each pair of brackets is to be multiplied together thus :

$$(8 + 1)\ (3 + 2) = (9)\ (5) \text{ or } 9 \times 5 = 45.$$

$\sqrt{\ }$, $\sqrt[3]{\ }$, $\sqrt[4]{\ }$ are signs respectively showing that the square, cube or fourth root of a number has to be extracted, thus :

$$\sqrt{64} = 8.$$
$$\sqrt[3]{27} = 3.$$
$$\sqrt[4]{16} = 2.$$

An expression, such as x^2 means that the number to which the index is attached has to be raised to the power denoted by that index, thus $2^2 = 2 \times 2 = 4$

$$2^3 = 2 \times 2 \times 2 = 8$$

An expression, such as $x^{\frac{3}{2}}$ is the same as $\sqrt{x^3}$; thus $4^{\frac{3}{2}} = \sqrt{4^3} = 8$.

Brackets ( ), { }, [ ] are employed to show that the quantities within them are to be treated as though forming one quantity, thus a — (b—c) is not the same as a—b—c, for in this last both the quantities b & c are subtracted, whereas in the former b—c is to be subtracted.

An expression such as

$$\log x = \log b + \left(\frac{\log D}{4}\right)$$

means that, if the logarithm of the quantity b is to be added to one-fourth of the logarithm of the quantity D, the result will be the logarithm of the quantity x. For explanation of the word 'logarithm' see the glossary.

A MANUAL

OF

HYGIENE, SANITATION AND SANITARY ENGINEERING.

INTRODUCTORY.

PUBLIC HEALTH is one of the most serious concerns of the State; Government, in that view, has created district and municipal boards, to whom has been confided the duties of fighting against and improving those insanitary conditions which prevail wherever men collect in communities of greater or less extent. These duties include the construction and maintenance of roads, the cleansing of towns, the laying down of sewers, the distribution of a supply of water, vaccine operations, and as a sequel, the collection of taxes; the end aimed at is either the removal of insanitary conditions or protection against disease caused by their presence. There are also a few other duties cast upon these boards, such, for instance, as the registration of births and deaths; but even this object is one intimately connected with those previously enumerated, as the resulting figures show to what extent the measures taken have benefited the people, or how far these have failed to secure the results intended to be attained.

No better criterion of results can be found than a satisfactory death-rate: so long as such a rate is not achieved, so long must efforts be made to attain it. The death-rate must vary to some extent with locality, climate and season; but a high average rate indubitably shows that there is something wrong and that insanitary conditions prevail. Nor, when a satisfactory death-rate is attained, may these efforts be relaxed: it is only by continued perseverance that such a rate can possibly be maintained.

A maxim which may well find its application to India is '*Laborare est orare.*' It is much to be regretted that, often in the presence of an epidemic in many parts of the

Empire of Queen Victoria, and perhaps more especially in the smaller villages and towns, the first portion of the maxim finds no place, while the second grants no relief. If it is only in times of terror that spasmodic attention is given to sanitary requirements, money is simply wasted in fruitless efforts to stay an epidemic which might have been altogether prevented. Man, indeed, in such cases, is his own enemy, for Providence helps only those who help themselves, a lesson well conveyed in the following letter which was addressed by Lord Palmerston to the Moderator of the Presbytery of Edinburgh in 1853:—

"I am directed by Viscount Palmerston to acknowledge the receipt of your letter of the 15th instant, requesting on behalf of the Presbytery of Edinburgh to be informed whether it is proposed to appoint a day of national fast on account of the visitation of the cholera, and to state that there can be no doubt that manifestations of humble resignation to the Divine Will and sincere acknowledgments of human unworthiness are never more appropriate than when it has pleased Providence to afflict mankind with some severe visitation; but it does not appear to Lord Palmerston that a national fast would be suitable to the circumstances of the present moment.

"The Maker of the Universe has established certain laws of nature for the planet in which we live, and the weal or woe of mankind depends upon the observance or neglect of those laws. One of those laws connects health with the absence of those gaseous exhalations which proceed from overcrowded human beings or from decomposing substances, whether animal or vegetable; and those same laws render sickness the almost inevitable consequence of exposure to those noxious influences. But it has, at the same time, pleased Providence to place it within the power of man to make such arrangements as will prevent or disperse such exhalations as to render them harmless, and it is the duty of man to attend to those laws of nature, and to exert the faculties which Providence has thus given to man for his own welfare.

"The recent visitation of cholera, which has, for the moment, been mercifully checked, is an awful warning given to the people of this realm that they have too much neglected their duty in this respect, and that those persons with whom it rested to purify towns and cities and to prevent or remove the causes of disease, have not been sufficiently active in regard to such matters. Lord Palmerston would, therefore, suggest that the best course, which the people of this country can pursue to deserve that the further progress of the cholera should be stayed, will be to employ the interval that will elapse between the present time and the beginning of next spring in planning and executing measures by which those portions of their towns and cities, which are inhabited by the poorest classes, and which,

from the nature of things, must most need purification and improvement, may be freed from those causes and sources of contagion, which, if allowed to remain, will infallibly breed pestilence and be fruitful in death, in spite of all the prayers and fastings of a united but inactive nation, when man has done his utmost for his own safety, then is the time to invoke the blessing of Heaven to give effect to his exertions."

Cleanliness of person is no less a necessity than street cleansing or a pure water-supply. The projection and adoption of improved methods of sanitation for the general good will indubitably fail if, at the same time, similar measures are not taken with reference to person and home. It is the duty of the State to initiate and promote sanitary measures, but the co-operation of the people themselves is necessary to make the result a success; to increase sanitary knowledge, to remove passive resistance, to dispel ignorance is therefore the first duty of all Sanitary Officers.

To make satisfactory improvements in towns and villages, all interested officials should have some acquaintance with those laws and rules which guide engineers in designing works for drainage or water-supply, and with those to which the sanitarian has recourse when considering the conditions which are most favourable to a healthy and protracted life.

To collate and explain some of such laws and rules is one object of this work, a second is to describe methods of practical application of such laws with special reference to such works as ordinarily fall within the scope of municipal institutions.

But, though some of the principles, on which the engineer or the sanitarian respectively conducts his profession, may be thoroughly understood, let it not be imagined that there is no use for these officers. It is trusted that these pages will rather tend to show how necessary their services are and how far proposed sanitary improvements may be advantageously discussed before professional aid should be solicited for advice upon measures for improvement.

The duties of a sanitarian require perseverance, firmness, tact and skill and, above all, zeal tempered with discretion; while sustained exertion alone can affect permanent improvements, it is unwise to unduly hasten sanitary measures in the face of interested opposition; smaller measures may be approved where larger schemes would not find acceptance; as the constant dripping of water will wear away a stone, so, constant demands for attention to sanitary

defects and resultant evils will eventually diminish, if not dispel, opposition. Nor is it wise to endeavour to thrust English methods on Indian towns; all schemes to be successful must be acceptable to the people and suitable to their habits.

Many works which boards may be advised to execute may seem expensive and, perhaps, call for an increase of taxation on an already burdened people. Poverty is undoubtedly a great bar to sanitary improvement, but it goes hand in hand with disease, and the amount of preventible disease in our towns can hardly be over-estimated, though it has been reckoned that to these nearly four-fifths of the registered mortality in India is due. The rate of mortality in a town should not exceed 19 or 20 per thousand, and, for every case of life saved, it is reckoned that about 28 cases of sickness are preventible. It has been calculated that, in a town of 50,000 people, the preventible deaths and sickness due to disease cost a community over Rs. 1,00,000 per annum.

Public morality goes hand in hand with public cleanliness, as does vice with dirt. Familiarity with dirt is a powerful factor in debasing morals. The constant presence of filth and the increasing difficulty of removal blunt the senses of sight and smell. Common decency and self respect are difficult to maintain in a surrounding of uncleanliness.

The financial and moral arguments are equally strong. The task of sanitary improvement is one in which the poor as well as the rich can aid, but it is one which requires an intelligent application of natural laws, and in this view it is hoped the following chapters will appeal to those engaged in the great work of sanitation.

CHAPTER I.

HYGIENE.

AIR.

Pure air necessary to health.—A high degree of health cannot be attained without pure air, and it has been ascertained by the statistician that the most frequent cause of death is impure air.

Constituents of pure air.—Pure atmospheric air consists of oxygen, nitrogen, and carbon dioxide in the following average proportions :—

	Parts per 100.
Oxygen	20·96
Nitrogen	79·00
Carbon dioxide	0·04
	100·00

Nitrogen has no active properties, but oxygen is essential for animal life ; the proportions of nitrogen and oxygen vary in different localities, there being less of the latter in towns than in the country. Ozone, a very active form of oxygen, is found in very pure air. Carbon dioxide is given out by the respiration of animals and is absorbed by plants. In crowded places the proportion of carbon dioxide is considerably increased. Air containing more than 5 per cent. will not support life, while 1·5 per cent. will affect most persons injuriously. Carbon dioxide is the gas evolved from the combustion of wood, coal, &c., from decaying vegetable matter, and is found in old unused wells, &c.

Natural air is never pure ; it is being constantly polluted and also purified. Its impurities are due to living animals, to decaying organic materials and to dust due to the disintegration of mineral substances. It is purified by the action of wind, by rain and dew and by gravitation.

Air impurities.—Impurities in air are gaseous or solid. Gaseous impurities consist of an excess of carbonic acid, carburetted hydrogen, sulphurous acid, phosphuretted hydrogen, and vapours arising from sewage, putrefying animal

matter, &c. Solid impurities are suspended in the air and consist of substances, organic and inorganic. Winds raise dust and soil with 36 to 46 per cent. of organic matter; particles of dead animals, hair, cotton, wool are often present, while excretions, urinary or fæcal, will abound in the air around filthy places.

Effects of impurities.—These impurities may take effect in various ways. Thus, air, polluted by decomposing matter, may cause nausea, vomiting, fever, diarrhœa. Mineral dust causes diseases, such as bronchitis and asthma; the dust arising from certain trades is poisonous. Microbes, the specific cause of certain diseases, live and are transported in the air.

The means for removal of impurities include disinfection by chemical means, heat filtration, and ventilation.

Disinfection.—Disinfection implies dealing with infection in a wide sense; it includes purification of any kind whatsoever; the burning of volatile substances, the application of liquids, the sprinkling of powders are most feeble substitutes compared with other means. The efficacy of disinfection is in inverse ratio to the area or capacity dealt with. All conservancy operations for the removal of filth may be considered disinfection; where matters and substances are not removable, washing, scraping, dusting and other processes may be resorted to; the more temporary measure of treating organic decomposing matters chemically is that popularly known by the name of disinfection, because the substances used in the process are styled disinfectants.

The object of disinfection is to destroy infective matter which, when received into the body of an apparently healthy person, has the power of producing disease. There is little doubt that this infective matter is a living organism or its product, and therefore disinfection must be able to destroy both the one and the other. Some organisms are difficult to destroy, spore bearing organisms are the most tenacious, therefore 'disinfectants' suitable in one case are useless in another.

Disinfectants.—The following disinfectants are in use (their proper application is indicated in the appendix): sulphurous acid gas, chlorine, iodine, crcolin, corrosive sublimate, sanitas fluid, carbolic acid, permanganate of potash (Condy's fluid).

Heat is the most certain disinfecting agent and may be applied in two forms—moist heat and dry heat. Boiling for 15 or 20 minutes is effective. To such articles as cannot

be boiled, dry heat may be applied as by baking or moist heat as by steam. Hot air is less effective than steam, but, to some articles such as leather, furs and articles in which glue is used, this latter process cannot be applied. The following table shows the time of application necessary when dry heat is the agent :—

Temperature.	Duration required.	Application.
212° F. ...	90 minutes ...	For the destruction of sporeless bacteria.
230° F. ...	90 do. ...	Spores of fungi.
284° F. ...	180 do. ...	Spores of bacilli.

On the other hand, the results by steam at 212° F. show that even anthrax spores are killed in 5 minutes. Each town ought to possess a disinfecting chamber; for small towns and villages portable apparatus can be had at a not excessive cost.

Large quantities of disinfectants necessary.—Large quantities of disinfectants are necessary for the large volumes of air likely to become infected or impure by reason of local conditions, and while, therefore, disinfectants are extremely useful, they can never take the place of, and must always be subsidiary to, ventilation.

Ventilation.—Ventilation is the replacement of impure air by pure air, and such action should not be limited to our dwellings, but be extended to the streets, squares, and lanes of our towns and villages.

Quantity of pure air necessary for health.—A certain quantity of pure air is necessary for health, and as a man in breathing adds to the air 0·6 of a cubic foot of carbon dioxide per hour, it is evident that, as carbonic acid is extremely poisonous, if fresh air were not obtained, the air would become so impure that he would cease to live.

Carbon dioxide when perceptible.—Carbon dioxide in the air is not perceptible to the senses until it is increased by a ratio of 0·02 per cent., and 0·06 per cent. may therefore be taken as the limit of respiratory impurity.

Amount of air discharged per person.—An adult discharges 16·66 cubic feet of air per hour, of which, as before stated, 0·6 of a cubic foot or 36 parts per 1,000 is carbonic acid. This quantity amounts to one hundred and eighty

times that which has been fixed as the limit of respiratory impurity per 1,000 volumes and, therefore, to keep the air pure, a supply of one hundred and eighty times the amount of air breathed or $180 \times 16{\cdot}66 = 3{,}000$ cubic feet per hour is required. As, then, pure air contains ·04 per cent. of carbonic acid, and as respired air contains, in addition to the carbonic acid, aqueous vapour, organic matters, and exhalations from the skin, it may be concluded that the *minimum* required is not less than 3,000 cubic feet per individual per hour.

Amount of air required for Barracks, &c.—Hospitals, barracks, and such places require a larger supply which may extend to 4,500 cubic feet per hour. For combustion also provision must be made; an ordinary oil lamp generates half a cubic foot of carbonic acid per hour, and requires 400 cubic feet of air; a candle requires 500 cubic feet.

Ventilation.—Ventilation, as has been explained, requires the replacement of impure air by pure air, and, without reference to the means by which that replacement may be effected, there must be motion in the air. Too great a motion will incur a perceptible draught, but any current of air moving at less than 2 miles per hour is imperceptible; it is therefore desirable for comfort that such velocity should not be exceeded. The rate may be regulated by reducing or increasing the sizes of the circulating openings. As large rooms are more easily ventilated than small ones, in the latter more numerous ventilators and a larger cubic space per head should be allowed. Supposing a current of 2 miles per hour or 3 feet per second is allowable, then to admit 3,000 cubic feet of air per hour, the area of the inlet opening required would be 40 square inches.

Regulation of supply of air.—The flow of air into any space cannot, however, be always kept at the same speed, there being so many different agencies in operation to contend against; while therefore the necessity for at least 3,000 cubic feet of air per person per hour should always be kept in view, and for that amount being delivered at a velocity not exceeding 2 miles per hour, the amount of cubic space necessary for an individual cannot be decided on such basis alone, even though the area of the circulating openings may be increased or diminished at pleasure.

Amount of cubic and superficial space required per individual.—Thus, while it is possible to ventilate overcrowded rooms, the rate of flow of air required would cause discomfort, and it is therefore found necessary to lay

down certain rules as to the cubical and floor space which should be allowed per person. In calculating the cubical contents of a room, the space above 14 feet from the floor is not considered as useful for ventilation, and an ordinary rule is that the floor area (square measure) ought not to be less than one-twelfth of the cubic space (cubic measure).

It is believed that a space of 1,000 cubic feet of air per head gives the best results, a larger cubic space causing stagnation of air; the floor area corresponding would be $\frac{1000}{12} = 83$ square feet. The following are allowances in India:—in the barrack rooms on the plains, 1,800 cubic feet and 90 superficial feet are allowed per person; on the hills 1,200 to 1,400 cubic feet and 75 superficial feet; in native hospitals 1,500 cubic feet and 99 superficial feet; in jails 648 cubic feet and 54 superficial feet. It is probable that these figures or some of them include space above 14 feet in height. Common lodging houses in England are licensed to lodge not more than one person for each 240 cubic feet and 30 superficial feet. Cattle ought to have 1,000 cubic feet. The outlets for air should be of the same area as the inlets, and the air should be introduced into a building so as to be distributed. It is well to allow the in-coming air to enter some height above the floor level, and this may be effected through Tobins and other tubes, ventilators, &c.

Methods of ventilation.—The various methods by which ventilation may be effected, may be divided into two classes, the natural and the artificial; the former includes winds and differences of temperature; the latter, extraction or propulsion. The wind is a very powerful agent in ventilation, and for the ventilation of streets, lanes, &c., on it to a great extent, dependence must be placed.

Natural ventilation.—In laying out new streets, when extending a town or village, or in cutting through portions of an existing town or village, the line of the street should, as far as consistent with other requirements, run in the direction of the prevailing winds. Winds, of course, pass through walls of wood, leaf huts, &c., and thus in such buildings a large cubic space per person is not such a necessity as in more permanent buildings. Wind, however, is not always a satisfactory agent; it may blow from a direction where insanitary conditions prevail, and looking to this fact it may be remarked that all such places as slaughter-houses, sewage farms, cattle depôts, rubbish depôts, &c., should be

placed on that side of a village or town from which the winds blow least frequently.

Circulation of air.—A movement of air caused by differences of temperature is called circulation. This means of ventilation in India is not generally applicable, because it entails the condition that the impure air shall be of a higher temperature than the pure air, as in such condition it is lighter and rises. Here in India, however, the air of our houses on the plains may be either cooler or warmer than the outside air, or the temperatures may be the same. There may, therefore, be either upward or downward currents or none at all.

Extraction of air.—Circulation may, however, be attained by artificial means and it is then called extraction. This may be by fires at the bottom of chimneys, which require a certain amount of air; this when heated rises and passes away, its place being taken by fresh air, or the air may be drawn out by a fan.

Propulsion of air.—Propulsion, however, is an easier means of supplying fresh air, and good instances of this method are the ordinary thermantidote and the punkah.

Measurement of flow of air.—The rate of flow of air is measured by an instrument called an anemometer, a description of which will be found in the chapter on meteorology.

Ventilation of stores, &c.—Before concluding the subject of ventilation, it may not be out of place, though the matter is one unconnected with hygiene, to note that all such places, as kerosine stores, match stores, fireworks manufactories or other places where explosive or combustible materials are stored, should be thoroughly ventilated. For such ventilation in India the wind must be depended upon. If cowls are arranged on a building, and these are continued by a shaft through the roof, then by the passage of the wind over the cowl at right angles to the shaft, the air is drawn up the shaft. This method of ventilation is called aspiration and is, of course, also applicable to buildings generally. It is probable that a fixed double cowl will act in a similar manner, but it is advisable to point out that such contrivances are most effective when least required, viz., when there is plenty of wind.

Examination of air.—Though many impurities in air cannot be recognised by smell, yet on that sense most persons must depend for the discovery of any impurity. Where

disease or filth is present, there will always be impurity, and under such circumstances ventilation, disinfectants, and deodorants ought to be freely resorted to. The microscopical and chemical examination of air presents many difficulties except to chemists or medical men, and, as many instruments and chemical solutions are required for the purpose, the examination should always be entrusted to such scientific persons.

Sulphuretted hydrogen, however, can easily be detected with the aid of lead test paper prepared by soaking white bibulous paper in solution of lead acetate. The paper, when dry, is cut into strips and enclosed in a bottle with a small lump of 'sesqui-carbonate of ammonia' wrapped in a fold of bibulous paper. If these strips of paper are placed in an impure atmosphere, discoloration takes place. If there is a slight discoloration within 10 minutes after exposure, the atmosphere is dangerous.

Test for carbonic acid.—An excess of carbonic acid in air can also be detected in the following manner, the process being based on the fact that an excess of carbonic acid causes turbidity when mixed in certain proportions with a solution of lime water. As already stated, the air of a room ought not to contain more than ·06 per cent. of carbonic acid, and, if it be desired to ascertain whether the proportion is more or less than this amount, the process is to take a 10-ounce bottle, clean and dry inside, and fill it with the air of a room by means of the bellows or syringe, then add half an ounce of clear saturated lime water, replace the stopper and shake briskly. If any turbidity appears, the air contains more than ·06 per cent. of carbonic acid.

As a preliminary to such tests all premises ought to be inspected inside and out, and all foul matter removed from the vicinity. Ventilating door, window and other openings should have careful attention. In respect to ventilation, the examination should be made immediately after a room has been used by the maximum number of persons usually occupying it.

WATER.

Existing sanitary conditions of villages due to want of wholesome water.—Wholesome water is, without doubt, one of the greatest requirements of all towns and villages in this country. To its want is due their insanitary condition, a condition aggravated by the habits of the more ignorant classes of the population, who, in many cases, use

the tanks whence their drinking supplies are drawn for purposes of washing their clothes and bodies. To any one familiar with this country this pollution is daily brought within their observation ; people habitually defile the slopes and margins of tanks, and then cleanse themselves in the water.

Indian sanitary laws in regard to water.—The late Surgeon-General Furnell, when Sanitary Commissioner for Madras, pointed out that numberless laws and regulations had been laid down by the ancient Indian law-givers to prevent water being defiled, and quoted the following :—

In the Yajurveda, the part called Arana contains the following commandments :—"Do not spit out with retching in the water. Do not pass urine or discharge excreta in the water. Do not drop blood into water. Do not throw any hair, or nails, or bones, or ashes, nor dip dirty clothes into water. For to do so is to abuse a precious gift of the gods and discharge them."

"II. Then, passing on to the Smritees, or the rules laid down by the law-givers regarding the use and abuse of water, the following are universally quoted authorities :—

"Yagnya Valkya prohibits the drinking of eight kinds of water—(1) water kept boilt by a stranger, (2) foaming water, (3) heavy dirty water, (4) water giving off offensive smells, (5) water rising in bubbles, (6) hot water, (7) muddy water, and (8) salt water.

"The sage Sáthathapa prohibits bathing in a tank or pond defiled by the following persons by washing or bathing :—Those suffering from sore-eyes or itch on the head or ear, those subject to epileptic attacks, or ulceration in the head running off through the nostril, or to consumption, or those affected by leprosy, or small-pox, or diarrhœa, cholera, or other contagious diseases.

"III. In the second book of Ramayana, the great epic poem of the Hindus, Prince Barata calls down upon himself a curse, if he were guilty of something charged against him, by saying,

'His sin, who deadly poison throws,
To spoil the water as it flows;
Lay on the wretch its burden dread,
Who gave consent when Rama fled.'

"The sin of spoiling drinking water was evidently considered by Prince Barata as one of the greatest possible gravity, as rendering the man who did it fit only for the infernal regions.

"IV. In Uddhava Gita of the eleventh book of the Bhagavata Purana, or Krishna's legend, the pious old Uddhava is advised by Krishna to drink no other water but that filtered or strained through a clean cloth. (Krishna evidently knew nothing of the modern improved charcoal filters.)

"V. Again, the sage Yagnya Valkya prohibits the use of water that remains after washing one's feet or hands and the

private parts of the human body, or the remnant of what another person drinks, or the water near the Dhoby's place for washing clothes, or where chandalas or butchers, chucklers, and other outcastes wash themselves, or where women after menses or child-birth, or people under pollution bathe."

The great law-giver, Menu, in Chapter IV of Manu Dharma Sastra, says :—

"Let him not cast into the water either urine or ordure, nor saliva, nor cloth, nor any other thing soiled with impurity, nor blood, nor any other kind of poison."

All these authorities are taken from the chapter headed Acharakanda, on the use of water, in the book of the Hindu law by Vaidyanadha, held in high esteem by the Hindu community of Southern India.

Carelessness in regard to water-supplies due to belief in their innate purity.—The general carelessness on the part of the people must, therefore, be due to a blind mistaken belief in the innate purity and undefilability of all large bodies of water or else to heedlessness.

Water classified. — A pure and sufficient supply of water is as essential to health as a supply of pure air.

Chemically, pure water consists of 2 volumes of hydrogen gas to 1 volume of oxygen, or by weight 2 parts of hydrogen to 16 parts of oxygen.

Good water is transparent, colourless, odourless and tasteless. Good water is not one chemically pure, indeed no chemically pure water has ever been found. In all water some chemical impurity will exist, but when it is desired, to fix the proportion such impurities ought not to exceed, it is found, that considerable differences of opinion exist.

Generally speaking, calcareous waters moderately charged with carbonate of lime are the most wholesome for drinking. Pure water is not suitable for drinking purposes, for, besides being insipid and uninviting, it may be unwholesome. Bright spring water such as is both pleasant and wholesome is, strictly speaking, very far from pure. It contains in solution gases to which its sparkling appearance is due and to which it also owes its invigorating and refreshing effects. It also contains a certain amount of earthy matter such as carbonate or sulphate of lime, or similar salts of magnesia. Dr. Letheby, from investigations he made, came to the conclusion that from 5 to 20 grains of salt per gallon is necessary to render water in the highest degree wholesome for drinking. The Rivers Pollution Commission on the domestic supplies of Great Britain, who examined more than 2,000 samples of

drinking water and inspected a large number of water works, and who received information from all parts of the country, say, in their report of 1874, "that in respect of wholesomeness, palatability and general fitness for drinking and cooking, their researches led them to the following classification of water in the order of their excellence, and founded on their respective sources:—"

Wholesome..	1. Spring water.	Very palatable.
	2. Deep well-water.	
	3. Upland surface water.	Moderately palatable.
	4. Stored rain water.	
Suspicious ..	5. Surface water from cultivated land.	
Dangerous..	6. River water to which sewage has access.	Potable.
	7. Shallow well-water.	

All these various classes of water have one and the same origin, viz., rain, which when it falls on the surface of the earth, is partially evaporated, the greater proportion flowing over the ground or sinking into the soil. The water flowing over the surface passes towards and forms streams, rivers, tanks, &c., carrying along with it many impurities. The water, which sinks into the soil, dissolves the soluble substances with which it meets and forms the wells; the rate of flow depends on several circumstances which will be explained when dealing with sub-soil water more particularly.

The reasons for the classification adopted above will be seen from the following:—

Spring water is water derived from fissures in an impermeable stratum overlying the stratum wherein the water is stored, and which has received it at a higher level. Spring water is practically identical with artesian well water and though it may be charged with mineral impurities is likely to be free from any of an organic nature.

Deep wells, if bored through an impermeable stratum should furnish water of a similar description if properly protected from surface and sub-soil pollution as will be indicated hereafter.

Upland water is that derived from higher ground. Its quality is dependent on the nature of the soil and its purity on the class and condition of the vegetation of the gathering area, and on the exclusion of inhabitants and animals from that area.

Stored rain water is the best water for washing purposes. It is liable to be impure in large towns from air and

dust, from impurities on the surface on which it fell, from imperfect methods of storing, &c. It is, however, an important source of supply and in many parts of India such as Cochin, for instance, is the best water available : further remarks on this subject will be found in the chapter on water-supply.

Surface water from cultivated land is more likely to be dangerous than any of the foregoing supplies, because of the consequent presence of people and animals in the air or vicinity of villages, &c.

River water to which sewage has access is undoubtedly dangerous and it is well not to draw water especially in India directly from the river ; if this is necessarily done, after-filtration must be resorted to. In the rains an accumulation of all kinds of dirt and filth is washed into the rivers. With very large rivers the impurities are greatly reduced by the process known as 'self purification,' but in any case filtration is desirable and careful filtration sometimes results in a fairly pure supply. Thus the supply of Calcutta is derived from the Hooghly which, when obtained, contains solids amounting to from 70 to 1,850 parts per million parts of water ; 50 to 100 per cent. of these are removed by settling and the water afterwards filtered and delivered clear and transparent to the consumer in Calcutta. River water may be indirectly obtained by means of wells sunk in the banks or bed of a river, or by means of galleries constructed adjacent thereto.

Shallow well water, in which may be included water from tanks, unfortunately the most ordinary source of supply in India, is the most dangereous, the pollution of the adjoining sub-soil naturally flowing towards the well. The surroundings of wells in Indian villages easily account for the high annual death-rate, and the constant presence of such diseases as cholera, typhoid, &c.

Hardness of water.—Before describing more particularly the impurities found in water, one quality of water which at once attracts notice will be referred to and that is the quality known as 'hardness,' the degree of 'hardness' which a water possesses being known by the greater or less amount of soap necessary for cleansing purposes.

This varying degree of hardness is of two kinds—one temporary, the other permanent. Temporary hardness is a quality which can be removed by boiling ; it is due to the presence of carbonic acid gas which retains in solution a

considerable amount of the carbonates of lime and magnesia: boiling expels the gas and separates the earths which are apt to cake on the vessels in which such water is boiled. Permanent hardness cannot be removed by boiling, because it is caused by salts such as those of magnesia and lime.

The fact that in using a 'harder' water, it is necessary to use more soap than with a comparatively softer water introduced one method of estimating the hardness by the proportion of soap which it renders insoluble. By 'degree of hardness' according to this test which is known as 'Clarke's test,' it is meant that water possesses as many degrees of hardness as would be imparted to it by so many grains of carbonate of lime. For instance, 'one degree of hardness' means that degree of hardness which would be imparted by one grain of carbonate of lime in a gallon of distilled water.

It does not, however, actually follow that waters do contain the proportion of lime indicated by the particular degree of hardness attached to them, but they have such a degree of hardness as would be imparted to them if they contained such quantity of lime.

Water for domestic purposes should be sufficiently soft to allow of comfortable and economical use for washing purposes and should, therefore, not exceed 20 degrees of total hardness nor 6 degrees permanent hardness. A water which has more than 10 degrees of 'hardness' is usually called a 'hard' water and water below that degree is called 'soft' water.

It has been thought that hard waters were prejudicial to health, but this has never been shown to be the case and as a fact hard waters are very often preferred.

The question, as to whether hard or soft waters are best for a town's supply, has been much discussed both in France and Austria. A Commission of Chemists on the water-supply of Paris rejected a soft water for a hard. They did so, because they considered that water supplied to a large city should possess certain qualities which a very soft water rarely possesses. At Vienna a similar preference was shown; a commission declared in favour of a water of 12·6 degrees of hardness.

The general characteristics of a hard water which render it better adapted for the supply of a town are these: it is generally bright and clear and well ærated, it is pleasant to the eye and grateful to the palate. In the next place it is

not supposed to absorb foul gases. It is generally so charged with gases that it has little or no tendency to absorb others. It is not liable to putrefaction : the organic matter is small and is better preserved than it would be in a soft water.

Examples of degrees of hardness.—The following table shows the hardness of some supplies used for domestic purposes :—

	Degrees of hardness.	
	Temporary.	Permanent.
Windermere lake	1·6	2·4
Loch Katrine (Glasgow)	...	0·9
The Thames (Reading)	12·8	8·2
Do. (Hampton)	17·9	6·6
Red Hills Tank (Madras)	2·8	3·5
Vigai (Madura)	6·6	0·3
Vennár (Tanjore)	0·3	1·7
Ádóni Tank	0·7	1·4

Air necessary in water.—Air is very necessary to render water palatable : as a case in point, distilled water in which air is deficient is not pleasant to the taste. Air can always be artificially supplied to water by forcing it in, or by letting the water fall in small streams from as great a height as possible.

The impurities, which are found in water, may be divided into two classes—suspended and dissolved.

Suspended impurities.—Suspended impurities may be inorganic or organic, the former comprising silica, clay, chalk or other mineral matters. Such matters may produce diarrhœa, dysentery, &c. Tank and river waters, when turbid after rain, are to be avoided. Organic impurities consist of the debris of animal and vegetable organisms, living animalculæ, fæcal and excrementitious matters by which cholera and other diseases are propagated. Suspended impurities can be detected by the eye, if the water is put into a long glass tube and then held between the eye and the light ; they usually subside within 24 hours and can then be examined by the microscope.

Dissolved impurities.—Dissolved impurities may be gaseous or solid ; the gaseous substances are air, carbonic acid, ammonia, sulphuretted hydrogen, and marsh gas.

Carbonic acid in water.—Carbonic acid gives the water a sparkling appearance and can be injurious only when

it enables water to hold in solution large quantities of calcium, magnesium, &c.

Free ammonia.—Free ammonia is derived from the decomposition of nitrogenous organic matters, chiefly animal, in the water itself. It is almost always present and is not itself dangerous. If it is present in considerable quantities, it indicates pollution by urine, as urea (one of the chief constituents of urine) undergoes an easy process of fermentation which converts it into carbonate of ammonia.

Sulphuretted hydrogen.—Sulphuretted hydrogen is the result of a chemical combination between sulphates in solution and organic matter. The peculiar odour of this gas renders its presence easily detected.

Marsh gas.—Marsh gas is evolved in the slow decomposition of vegetable matter when air is excluded. Its presence is not supposed to be mischievous.

Dissolved solid impurities.—Dissolved solid impurities may be organic or inorganic. The former are taken up from the soil through which the water has flowed, or from animal or vegetable matter in the water itself, or by infiltration from burial grounds and other polluted places, or from sewage matters. The latter consist, amongst other matters, of sodiums, calciums, magnesiums, iron, lead in combination with chlorine, sulphuric, nitric, and other acids.

Chlorine indicative of sewage.— The amount of chlorine in drinking water is of itself of little importance, since it is common salt; if, therefore, some be taken in water it is of no consequence, but the presence of chlorine in water is indicative of sewage contamination. The reason for this is that natural water is often almost free from chlorine while, on the other hand, urine and sewage are highly charged (comparatively speaking) with chlorine. If, therefore, a water has no chlorine, it cannot have been contaminated with sewage; hence, from the amount of chlorine, the purity of water can be judged or measured, but only to a certain extent, for the absence of chlorine is no gauge in respect to vegetable contamination.

Carbonic acid and carbonates hurtful in too great quantities.—When speaking of hard and soft water, it was pointed out that the hardness was due to a considerable amount of carbonic acid gas, and, when referring to this impurity, it was stated that it was not hurtful unless it retained too great a quantity of carbonates of calcium and magnesium; these are two of the impurities to be found

included amongst inorganic dissolved solids and neither should be present in too great a quantity.

Analysis of water.—The analysis of water is a most important duty whether in regard to water proposed to be selected as a supply to towns or villages, or to existing supplies; ordinary examinations other than those preliminary as to colour, taste, odour, and clearness should be left to duly-qualified officers. The preceding paragraphs have, therefore, been written with the view of giving information to those who may occasionally have the results of water analysis placed before them rather than with the idea of including in this work details as to how quantitative and qualitative water analysis should be conducted.

Form of report on potable water.—The report on potable water, which is usually obtained from the office of the Chemical Examiner, Madras, is as follows :—

1. Total solids, in grammes per litre	.. =	$\frac{1}{1,000}$
2. Volatile solids, do.	.. =	$\frac{1}{1,000}$
3. Chlorine, do.	.. =	$\frac{1}{1,000}$
4. Total hardness, in degrees (Clarke).		
5. Permanent hardness, in degrees (Clarke).		
6. Free ammonia, in millegrammes per litre.	=	$\frac{1}{1,000,000}$
7. Albumenoid ammonia, do.	=	$\frac{1}{1,000,000}$
8. Nitric acid, do.	=	$\frac{1}{1,000,000}$

[NOTE.—There are 1,000 grammes in a litre, therefore the ratio of grammes to a litre is 1 to 1,000; similarly there are 70,000 grains in a gallon, therefore the ratio of grains to a gallon is 1 to 70,000. The one proportion is to the other as 1 to 70, so that by multiplying the first by 70 will give the second. To bring grammes per litre into grains per pint, multiply by 8·75.]

Albumenoid ammonia.—It will be noticed that, though free ammonia has been spoken of as one of the impurities in water, no mention was made of albumenoid ammonia. Chemists have a method of estimating the quantity of dangerous nitrogenous substances in water by finding out with great accuracy the amount of ammonia it yields when submitted to a particular treatment. Substances of the same class as albumen or white of egg and gelatine are productive of ammonia by the same treatment; any ammonia so produced is called *albumenoid ammonia*, that is to say, ammonia derived from substances resembling albumen or what is equivalent to ammonia resulting from the destruction of animal contamination. If a water has a considerable amount

of albumenoid ammonia and there be little or no free ammonia, the impurity is probably of vegetable origin and if chlorine is absent almost certainly so. Albumenoid ammonia co-existing with free ammonia, chlorine and nitric acid, shows the impurity as of animal origin and therefore very dangerous.

Absence of chlorine shows non-contamination by animal matter.—What is to be presumed from the presence of chlorine in water has been stated. An absence of chlorine shows that the water has not been contaminated by animal matter, so that, if there be much organic ammonia with an absence of chlorine, it may be concluded that the water is contaminated by vegetable matter. Chlorine may, of course, be present in water in large quantities, and yet the water may be perfectly pure. Such would be the case where the water is procured from land where salt abounds.

Nitric acid is a result of the decomposition of nitrogenous organic matter (recent pollution being shown by albumenoid ammonia) which, as decomposition proceeds, is replaced by free ammonia and nitric acid. Nitric acid may be derived from nitre deposits in the soil. It renders water likely to act on lead. The other impurities mentioned above have already been dealt with.

The following table will be of use when studying the results of water analysis:—

Nature of impurity and how stated.	Good water contains not more than	Usable water contains not more than	Suspicious water contains not more than
Total solids, grammes per litre.	0·071	0·428	0·714
Volatile solids, grammes per litre.	0·014	0·043	0·071
Chlorine, grammes per litre.	0·014	0·043	0·071
Total hardness, degrees, Clarke.	6°	12°	20°
Permanent hardness, degrees, Clarke.	2°	4°	6°
Free ammonia, millegrammes per litre.	0·02	0·05	1·00
Albumenoid ammonia, millegrammes per litre.	0·05	0·10	1·25
Nitric acid, millegrammes per litre.	0·32	5·00	10·00

The total solids include all the solid impurities—suspended and dissolved, organic and mineral;—the volatile solids

consist mainly of organic matter and may be regarded as a measure of its amount.

Collection of water for analysis. — In order to obtain accurate results by analysis, an important preliminary step is the proper collection of the water, in which operation the greatest care is not only desirable but also necessary. The quantity of water taken for analysis should not be less than half a gallon. One glass-stoppered bottle should be used, if this is not available then two or three clear ordinary glass bottles with new corks; the bottles ought to be thoroughly cleansed before being filled and this may be done by pouring into the bottle a little strong sulphuric acid and allowing it to flow over the inner surface, afterwards adding water and shaking it about until the acid has disappeared. The bottle should be nearly filled, but not quite, with the sample. The stopper should be tied down with a piece of linen or calico, and then sealed, and despatched for examination as soon as possible. In taking water from a river or tank, the mouth of the bottle should be kept closed until some little distance below the surface. In deep tanks it may be advisable to take samples at various depths; this may be done by means of a bottle arranged with a valve which can be opened when it has sunk to the required depth. In collecting water from street mains, the water ought to be allowed to run a little from the taps before reception in the bottle. *Collections of samples for analysis ought never to be entrusted to a servant.*

Preliminary tests of water.—While, as previously stated, it is not only desirable but imperative that water for potable purposes should, before any source of supply is selected, be analysed by well-qualified sanitary specialists, it is at the same time also desirable that sanitary officers should be able to make preliminary observations and the following rules, based on rules in the late Dr. MacNally's Sanitary Hand-book, will be found useful, it being presumed that the source has been examined with reference to possible contamination due to its site or surroundings.

1. Collect the water, observing the precautions already laid down.

2. Examine the water—

(1) In respect to clearness and colour, this may be reckoned comparatively by observing the depth of water, as compared with distilled or other known waters, through which a newspaper can

be read. Note whether there are any distinguishable objects, such as worms, leaves, insects, &c., and if there be any sediment whether compact or flocculent.

(2) In respect to taste by swallowing a portion.

(3) In respect to odour by shaking up a portion of the water in a clean wide-mouthed bottle ; if none is detected the water should be set aside and again examined after 24 hours have elapsed.

3. Microscopic examination may be made and it should be noted whether the sediment contains evidence of contamination such as rice or other grain, hair, fibres, wool, &c.

4. The water may be chemically examined thus —

(1) For reaction (acidity or alkalinity) by the immersion of blue and red litmus paper in the water. Good water ought to be neutral or faintly acid (from carbonic acid). The papers should, therefore, remain unchanged in colour or the blue paper become purple or faintly reddish. If the red paper becomes purple or blue, the water is alkaline. A strongly acid or any alkaline reaction should condemn a water unless the cause is known to be harmless.

(2) To test for organic matter, obtain two white glass bottles, a solution of 1 grain to 2 ounces of water of permanganate of potash and some distilled water. Fill into each of the bottles the same quantity of water, into one bottle the distilled water, into the other the water to be examined. Add to each a portion of the solution drop by drop until a pink tinge is acquired. Place both bottles against a sheet of white paper and examine for a quarter of an hour. The loss of the pink colour rapidly shows the water examined to contain a large amount of organic matter probably animal, if it loses its colour slowly the organic impurity is more probably vegetable ; if the pink colour remains, the water contains little organic impurity. If, however, a water has iron in it, this will cause the loss of the colour.

To detect iron in a water ; if in any quantity the taste will indicate its presence ; if in small quantity, evaporate a portion of the water to dryness and add a drop of solution of potassium ferrocyanide to the residue ; a blue colour indicates the presence of iron.

To detect ammonia in a water. Obtain Nesseler's solution which is made as follows :—30 grains potassium iodide and 10 grains mercuric chloride are dissolved in a pint

of warm, distilled or rain water; a strong solution of mercuric chloride is added drop by drop, stirring until a slight red precipitate is formed. 150 grains of caustic potash is now added and finally a little more mercuric chloride solution until a slight precipitate is produced. Allow this to subside and decant the clear solution for use. Drop a little of the solution into the water. A yellow or brown colour indicates the presence of ammonia or its salts. If a white milky precipitate is produced, lime or magnesia is present. This test is, therefore, a double one, the depth of brown or yellow colour depending on the amount of ammonia, and the degree of hardness on the amount of the whitish precipitate.

To test for chlorides, add to the water in a test tube a few drops of nitrate of silver acidulated with nitric acid; the presence of chlorides will be shown by a milky haze or precipitate.

To test for sulphates, add to the water in a test tube some drops of barium chloride acidulated with hydrochloric acid. Shake up and if a haze is produced, sulphates are present.

Magnesium salts are indicated by the production of a similar cloudiness on shaking after the addition of ammonia solution to a water.

The inferences to be drawn from the above examination and tests are—

(1) Colour, turbidity, odour or taste may be a sufficient reason for the rejection of a water, but a colourless, odourless, or tasteless water is not necessarily pure and fit for consumption.

(2) Strong acid or alkaline reactions should condemn a water, unless the reason is known to be harmless.

(3) Water, which rapidly decolourises permanganate of potash, is dangerous from the presence of organic matter unless iron is present.

(4) Water in which there is a well-marked colour produced in the ammonia test is polluted, as ammonia is usually derived from the decomposition of nitrogenous organic matter. If there is much white precipitate produced, the water is bad for cooking and washing, but may be suitable for drinking, if magnesium salts are not indicated by the test for these salts.

(5) Chlorides are present in most waters, a large quantity shows the water is brackish. This quality may be derived from the soil or it may be animal impurity. Thus a considerable quantity of chlorides *alone* cannot condemn a water.

(6) The presence of sulphates is evidence of dangerous mineral or organic contamination.

(7) Magnesium in sufficient quantity to give turbidity ought to condemn a water.

Such tests and considerations will afford a basis for opinion as to the suitability or otherwise of water, but in no case should any source of supply, especially for domestic purposes, be decided upon until a complete analysis by a chemist has been obtained. It is advisable also to have the water drawn from a proposed source at various times of the year, so that the effect of seasonal variations may be noticed, and it is no less necessary that town supplies should be regularly and carefully examined so as to guard against contamination and to ensure the continued efficiency of the means taken to prevent contamination.

While chemical examination is the ordinary method of detecting impurities in water, there has lately been introduced what is known as the biological test which consists in the cultivation, according to Koch's methods, of the microbes contained in water. The number of microbes in a measured quantity of water are counted, but there are no ready means of distinguishing disease causing microbes from those which are harmless to man. The system has not yielded very practical results and therefore, while it may be a useful auxiliary test, it is not likely for the present to supersede chemical examination.

Ice, &c.—Ice may be made of decomposing impure water or water drawn from the town mains may be stored in imperfectly-protected reservoirs or tanks before use. Ærated waters may also be made of impure water, the fact of impregnating the water with gas not giving any security, but it has been stated recently that such waters, a week or ten days after manufacture, become pure even though made with impure water. The statement is to be received with caution.

Effects of use of polluted water.—Polluted water is one of the most fruitful sources of disease. Cholera and typhoid can undoubtedly be transmitted from one person to a whole community through its agency. The effect of the introduction of purer supplies is everywhere very marked.

Before the introduction of the Red Hills water to Madras and when it was chiefly dependent on wells for its supply, the average deaths from cholera was 1,400 per annum; after the introduction, 200 per annum, but the Red Hills supply is not so pure as it ought to be. Nagpore, which used to have some-

times as many as 420 deaths per annum, had, on the first year after the opening of its water works, only one death and the deaths from cholera since (up to 1881) had not exceeded 60. In Bombay and Calcutta the reduction in the death-rate, after the introduction of water-supplies and other sanitary improvements, was most marked.

The following table shows the total death-rate in certain towns in England before and after the introduction of water-supplies :—

——	Population.	Expenditure on water-supply.	Death-rate per thousand.	
			Before.	After.
Chester	39,569	£74,816	30	23·3
Hull	149,000	£215,000	31	16
Manchester ...	1,000,000	£2,850,000	33	24

Purification of water.—It is the duty of the Engineer with the aid of the Health officer, to provide towns and villages with unpolluted supplies, but of some towns and villages the circumstances are such that new or improved supplies may be unattainable. The improvement of existing supplies may require works of considerable magnitude, but a description of these appertains more particularly to another chapter of this volume. Some methods of purification of water may, however, be mentioned here which can be adopted in order to make water suitable and safe for domestic use.

Boiling.—The first is boiling ; this is perhaps the most effective method as it is the safest, the action of boiling precipitates carbonates in solution, expels gases and destroys animal and vegetable origins.

Distillation.—If to boiling distillation (that is the turning of the whole water into steam and the reception and condensation of the steam in another vessel) be added, water nearly absolutely pure will be obtained. This method is sometimes used for the supply of towns and on boardship as sea water can be distilled and a pure supply obtained.

Precipitation of suspended matters in water can be obtained by four or five grains of alum per gallon. The fruit of the *strychnos potatorum*, when rubbed on the inside of a vessel containing suspended impurities, has a similar effect.

Filtration is the most eommon method of purifying water both on a large and small seale. The slower the filtration the more effeetive it is. Charcoal, sand, and other substanees are used. The three-ehatty filter is the most eommon method in India, the upper ehatty being half filled with ehareoal, the eentre with sand, the lower holding elear water only. It has been lately stated that the use of eharcoal is neither advisable nor neeessary and that indeed its effeets are not benefieial. Filtration twiee through sand would be more effeetive. It is not desirable to elean filters too often, the reason for this will be found on a later page; in faet, filters should be eleaned only when they fail to pass sufficient water through them at a proper rate. Sand from filters should be washed, heated and then returned to the ehatties, but the filtration will not be effieient for the first two or three days after eleansing.

By eareful filtration and after boiling, water ean be rendered almost safe, and in times of epidemie, boil your iee even, is not bad adviee to give.

FOOD.

There is no duty whieh, it is more important, should be effieiently performed than the prevention of, the sale or consumption of, unwholesome food, unfit for human consumption. The following pages therefore are devoted to a description of those diseases in animals, which render their earcasses unfit for eonsumption, and those eonditions, in fruits, vegetable, grains, &e., in which the sale and eonsumption should be prevented.

I.—Live Animals.

All animals brought for slaughter should comply with the following eonditions:—

The animal should not be very thin; it should be able to rise without diffieulty and walk without lameness. Its coat should be in good condition, its skin elastic and without sores, seabs or boils. Its eye should be bright, its mouth and nostrils moist but without diseharge. It should breathe easily and almost without noise; its breath should be without odour. It should not appear to be in any pain.

II.—Meat and Carcasses.

Good meat is firm and elastie to the toueh, moist but not wet, and, except in the case of pork, veal and lamb, bright red

in colour. If well fed it has sometimes a streaked appearance from layers of fat in the flesh. It has a fresh and not disagreeable smell. The fat should contain no watery juice; the suet fat should be hard and white.

A sound healthy carcass should be stiff as soon as thoroughly cool. It should be well-bled and no part of it darker than another. The red flesh on being pressed with the finger should not 'gut' (leave a hole), as this would indicate the presence of water, nor should it crackle as that would indicate air; other points to which attention should be directed are —

(1) The tongue and mouth should be free from blisters and dark spots.
(2) The lungs should be of a bright pink colour free from pus or worms. A portion cut off should float in water.
(3) The heart should not be yellow or have dark spots.
(4) The liver should be of a rich brown colour and free from abscesses and flukes.
(5) The spleen should be of a dark colour inside, grey on the outside long and thin.
(6) The stomach should not be red; the lining should not come readily off.
(7) The bowels should have a smooth whitish lining and free from dark or purple spots or ulcers.
(8) The hoofs should be firmly attached to the feet.

III.—Meat unfit for Food.

There are three conditions owing to which meat may be unfit for food:—

(1) By decomposition through having been kept too long.
(2) It may be got from an animal which has died a natural death or slaughtered when in a dying state.
(3) It may come from an animal affected by disease communicable or injurious to man, or from a poisoned animal.

The first condition is shown mainly by a bad smell, the outside is pale and bluish and at a later stage greenish.

The second condition is indicated by the dark colour of the meat, the amount of blood and by the carcass setting badly.

The third condition is the one most difficult to detect and the detection and seizure of such meat is one of the most trying duties of Sanitary officers, and to enable an officer to carry out such work efficiently he must have some acquaintance with the various diseases; he must observe closely and be able to judge properly of what he sees.

IV.—Diseases of Animals.

The most common diseases affecting animals are cattle plague, anthrax, foot-and-mouth disease, flukes, tubercule; these diseases can be detected by signs, apparent to the naked eye, of the internal organs thus—

Cattle plague.—Congestion of the inside surface of the stomach and intestines which may be covered with blood spots and blotches. Often large portions of these surfaces have peeled away leaving the inner parts exposed. The wind-pipe and bronchi may also be similarly affected, the heart flabby and blood not fully clotted. The flesh is quite unfit for food.

Anthrax.—The blood is black, not congealed, and diffused through the tissues. The spleen is much swollen and may have burst. Liver, kidneys and lungs are congested and marked with points and blotches of blood. The flesh is quite unfit for food.

Foot-and-mouth disease. — There are blisters on the tongue and inside of mouth tending to form ulcers. Nothing is specially characteristic in the appearance of the internal organs. The udder and teats are blistered and ulcerated, also the split in the hoof. There is a difference of opinion as to whether the flesh of animals so affected is fit for food.

Flukes.—These are visible in the sheep's liver and look something like minute plaice. There is evidence to show that the flesh may be eaten with impunity more particularly when salted and dried. Authorities differ as to this.

Tubercle.—There is very little doubt that this disease renders the flesh of an animal unfit for food and dangerous to man. It has lately been determined that the disease in man and cattle is identical, and the importance of this fact cannot be overrated, because in England one-fifth, in Madras one-fortieth and in Paris in 1880 one-fourth of the entire mortality is due to tuberculous maladies. It has been held that the removal of the diseased parts of an animal is not a sufficient safeguard, and that where an animal is affected, the whole carcass must be destroyed.

The Talmud, a commentary on the Mosaic law, whose ordinances are of equal authority, prescribes an examination of the principle organs of animals especially the lungs and requires the rejection of such as have adhesions between the tissues of the lobes or between them and the ribs, and also if there be pustules disseminated even superficially in the lungs. The lining must be insufflated and its expansion, so perfect that any rupture of its substance suffices for its condemnation. These ordinances are observed to this day by faithful Jews and the result is a peculiar immunity of their community from tuberculous diseases.

Carcasses of animals with young.—There is no reason for pronouncing these as unfit for food, unless there are signs of blood on the brain, or milk fever, the carcass ill set, and the meat pale, bluish or wet, to the touch. The same rule holds good in regard to animals killed by a blow, fall, choking, &c.

Carcasses of poisoned animals.—While the flesh may show no signs of disease, the bowels will likely be of a bright red colour with red spots. The stomach especially the first should be examined for signs of inflammation.

V.—Poultry and Game.

Poultry

"Good poultry should be firm to the touch, pink or yellowish in colour, should be fairly plump and have a strong skin. It has a fresh not disagreeable smell. Stale poultry loses its firmness, becomes bluish in colour, green over the first stomach and belly, the skin readily breaks, and the bird has a disagreeable odour.

"Poultry suffer much from an offensive discharge from the nostrils and eyes, from worms in the wind-pipe, from worms in the bowels (guts) from so-called diphtheria (membrane in wind-pipe) and many other diseases, but if the bird has been properly killed it may be passed. The only serious disease of poultry, which, there is reason to believe, may spoil the flesh, so as to make it unfit for food of man, is fowl-cholera. There is, however, little evidence of the disease in birds carefully prepared for the market. The flesh is somewhat redder than natural, the liver probably softer, and the heart speckled with red or dark spots often inside and out. If the bowels (guts) can be seen, they will be inflamed, with red spots or bluish patches. Domestic fowls, ducks, turkeys, geese and

pigeons, are all subject to the disease. Poultry affected with this malady, unless in cases when it proves very rapidly fatal, exhibit signs of suffering. Their feathers are bristling, their wings droop, they sway from side to side, drag their legs, eat nothing and drink much. The comb is flaccid and blue. There is diarrhœa, at first glairy, then frothy, and towards the end streaked with blood.

Game.

Game is rarely sold in a fresh condition. It is the fashion to bring it to market so 'high' that it is really in a state of active decomposition, so it cannot be seized unless it is found unmistakably putrid. Another point about game is, that it is liable to a disease like fowl-cholera. It is difficult for any one but a medical officer to declare game unfit.

VI.—Fish.

Stale fish is easy to distinguish from fresh fish; in the latter the gills are bright and red, in the former pale and discoloured. The flesh of the latter is stiff and elastic; the former is soft and pasty, a pressure by the finger leaves a hollow. Where fish is so stale that it smells, no further evidence is required.

VII.—Fruits, Vegetables and Grains.

Fruit.

Fruit may be subject to disease, or in a state of decay, or it may be so unripe (especially in the case of early windfall apples) as to justify seizure. Diseased or decayed fruit is known by softening, change of colour, and external mould (green coating); fruit may be bird-bitten or insect-bitten and none the worse, except that its appearance is spoilt.

Vegetables.

Potatoes and all fresh vegetables may also be the subject of disease or decay, and either softening or change of colour, or both, will mark the parts affected. Good potatoes are firm, the colour is pale and all alike and the juice is acid. Inferior potatoes are best known by their great lightness.

Grains, &c.

Most natives of India can discriminate between good and bad grain. Rice is the chief food and damaged rice is not

often exposed for sale, though probably used to some extent in the manufacture of sweetmeats. Grains of all kinds become mouldy from damp and then are more or less unfit for food. Mouldiness can be recognised by discolouration, and when excessive by the grains adhering to one another. Grains are also attacked by insects. New rice is unwholesome and its use ought to be discouraged.

VIII.—Milk.

Milk, ghee and curds constitute an important portion of the dietary of all classes of the people. Much of the preventable disease and mortality in our towns may, with some reason, be attributed to the unwholesomeness of our milk-supply due to the filthiness of cattle-yards and their surroundings. It requires no medical training to understand that the state of filth in which the cows are kept, the prevalence of disease amongst them and their attendants, the foul atmosphere of the sheds in which the milk is allowed to stand, the extent to which, and the sources from which, milk is diluted, are conditions quite incompatible with a pure supply. Milk is easily tainted by smoke gas or foul odours, and if kept in badly-ventilated places, soon becomes unfit for use. Milk, besides having water added to it, is often greatly adulterated with chalk, rice and other matters. The water used for adulteration is likely to be that from a well close to the cow-sheds and which is therefore most probably impure, or it will be obtained from some tank equally so in the neighbourhood. The necessity for strict regulations in regard to cow-houses, cattle-yards, dairies, &c., is therefore evident. What these regulations ought to be, will be found considered in that portion of this manual relating to House Sanitation.

Characteristics of good milk.—The characteristics of pure milk are a white colour, absence of deposit and of peculiarity of taste and odour. It should not curdle when boiled or alter in appearance. Its specific gravity should not fall below 1,026. An instrument called a "lactometer" is used for this latter test.

Milk tightly secured in a bottle while boiling with a little sugar added will keep for many months.

IX.—Tinned Provisions.

Large quantities of tinned provisions are now imporeed into this country. It is the practice of the larger dealers to

keep these only a certain time in stock, if not sold in the ordinary course of business. When this time has expired these provisions find their way to the smaller dealers and up-country stores. The only guide, an Inspecting officer can have as to the state of the food the tins contain, is the condition of the tins themselves. If these are hollow at the ends, their contents are probably wholesome; but if on the contrary they assume a convex shape, this is probably due to the gas generated by decomposition.

An awl or other sharp pointed instrument thrust through the tin will allow the escape of the gas. Such puffed cans should be confiscated and destroyed.

SOILS.

Selection of village-sites.—The elevation, conformation of any ground, its vegetation, its geological and chemical structure are all circumstances which have considerable bearing on the health of persons living on it. Soils are composed of mineral matters and near to the surface, but often to some depth, are mixed with animal and vegetable matters; this latter condition may be found where porous soils are superimposed on impermeable (or nearly so) strata. The denser soils such as granite, limestone, quartz, &c., do not contain organic matter and comparatively little air or water. The most healthy soils for the erection of dwellings are dry, gravel, laterite and sandy soils in which there is not an excess of clay. Ground also, which is extremely hard and non-permeable, forms a not unhealthy site. Damp porous soils, rich in decaying matter, are breeding grounds for microbes, and such soils are exceedingly unhealthy.

AIR AND WATER IN SOIL.

Sub-soil air.—Air and water exist in all soils excepting perhaps in the most dense rocks. Air driven from the soil is in an impure state, as it is contaminated by the gaseous products of decaying matters, and it is therefore desirable that such air should be kept out of dwellings. The flow of air from the soil is caused by two circumstances: (1) the alterations of the temperature; (2) the rise of the sub-soil water. To keep such air and water out of dwellings, the basements should be rendered impermeable; the planting of trees and herbage acts beneficially both as regards sub-soil air and water.

Sub-soil water is the water which is found in all porous soils. It is found sometimes near the surface, but often not for some distance * below it owing to the nature of the soil in which it is. The greater depth at which it is found the more healthy the site, but large or finite alterations in the level of the sub-soil water cause unhealthiness. Sub-soil water is not usually in a stagnant condition, but flows towards valleys where it finds its outlet in rivers, &c.; where the slope of the strata (independent of the slope of the country) is quick, the sub-soil water has, of course, a greater velocity, and ground over such strata is more healthy than where the strata are less inclined. The velocity of sub-soil water is extremely small, probably not exceeding, in ordinary circumstances, 100 feet per diem.† Great fluctuations occur in the level of the sub-soil water, when the valleys towards which it flows are flooded at the same time as the land, from which the sub-soil water is derived, is suffering from excessive rainfall or when the strata are called upon to carry off a quantity of rainfall derived from an area to which they do not extend as might be the case with strata outcropping at the bottom of an extensive range of hills.

A soil in which the sub-soil water is high and fairly steady is more healthy than a soil with the sub-soil water showing great fluctuations. Certain classes of diseases are rife when the sub-soil water is rising, thus expelling the ground air, and another set of diseases when the reverse action takes place: thus it is believed that enteric fever, cholera, diarrhœa and dysentery are prevalent at the time of low sub-soil water, while small-pox is said to prevail after a long draught and sudden rising of the sub-soil water. Typhoid fever is said to be more prevalent with a falling or low sub-soil level and it has been noted that a very low Nile marks an unhealthy period. The general conclusions are, therefore, that disease is increased not by absolute height of sub-soil water, though a low level is generally contemporaneous with unhealthy years, but that it is the fluctuation of the level of the water which causes an increase in the various diseases and a year will be proportionately unhealthy in regard to the number of fluctuations occurring. To keep sub-soil water at an average level is

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* In Western Rajaputana the water is at some places several hundred feet below the surface, but the sand is always damp a few feet below the surface.

† Pettenkofer at Munich found the rate as only 15 feet daily. Fodor at Buda Pesth found the mean rate 174 feet.

therefore desirable and one of the chief means by which this is attained is sub-soil drainage.

The irrigated tracts of the Madras Presidency are not, as a rule, unhealthy though it might be presumed from the foregoing remarks that they would be so. That this is not so is probably due to the general porous character of the soil and to the very perfect flooding which takes place and thus keeps up a constant change in the water. Irrigation, however, as a rule, should be accompanied or preceded by drainage. Otherwise where the soil is of a non-porous character its omission is the cause of malaria and fever such as is found in Northern India and in Italy. It is, however, also to be noted that an originally damp undrained malarious soil becomes more healthy by being irrigated and cultivated and less unhealthy than if left in its primal condition. The author investigated the value of certain recommendations in regard to the use of tanks, and the continuance of rice irrigation close to the town of Cuddapah and came to the conclusion that the stoppage of the irrigation was not necessary, nor the cause of the fever in the town due to the irrigation, but to the previously existing condition of soil. Where, however, the soil in the vicinity of houses is of a damp or malarious character, it is desirable that irrigation should not be encouraged.

METEOROLOGY.

Meteorology is the science which relates to the description and explanation of those phenomena which are included under the heads of weather, season and climate, the climate of a place being its condition in respect to temperature, humidity, pressure, movements and the electrical state of the atmosphere.

Air.—Man lives in an ocean of air which extends over sea, over land and much in height above the very highest mountains, and like the sea the air has its currents which are winds, and its waves are of great extent, but these are not visible to the eye.

Barometers.—As the air is distributed over the whole globe, each portion, say, a square inch, supports all the air directly above it, no matter to what height that may extend. The weight of this column, or what is called pressure of the air, is measured by an instrument called a barometer, of which there are two classes, one the ordinary mercurial

barometer, the other the aneroid; the latter is more convenient for ordinary purposes, but is less generally applicable for scientific purposes.

Principle of the mercurial barometer. — The barometer measures the pressure of the air by the height of the mercurial column supported. If a tube over 30 inches in length be filled with mercury closed with the finger and then placed in a vessel and the finger withdrawn, it will be found that the height of the columns of mercury is 30″ * or somewhat approximating to that height, for the pressure of the atmosphere is not in the same place always the same, but slightly varies from hour to hour and day to day. The above is a description of the mercurial barometer in its most simple form; it is ordinarily formed with an attached cistern with the bottom moveable by a screw and with scales to enable the height at which it stands to be easily read.

Pressure of air. — As the column of mercury is balanced by a column of air, the weight of the mercury will show the pressure of a column of air of equal diameter, and it is found that this pressure is equal to 15 lb. on each square inch, which is the pressure of the air at sea level.

Weight of air.—The weight of air may be found by weighing a bottle which contains nothing but air and then re-weighing after the air has been extracted; a cubic foot of air is found to weigh 564·8 grains or 27,810 cubic feet of air weigh 1 ton.

Corrections necessary in using the barometer.— In using the mercurial barometer certain corrections require to be made to ascertain the true reading and two constant corrections are necessary, those for capillarity and index error; the first depends on the bore of the tube and is usually notified by the maker, the latter error must be determined by reference to a standard barometer. Again barometer readings are always registered as if the readings were taken when the temperature was 32 degrees or freezing point on the Fahrenheit scale. But if the temperature be above this, then the expansion of the mercury will make the reading higher than it would be at 32 degrees, and if the temperature is lower, lower. There is also the reduction to sea level; this is necessary for purposes of comparison.

* A pressure of 30″ mercury equals that of about 34 feet of water.

The following table gives the necessary corrections for reduction to freezing point :—

Table for Reduction of Barometer to Freezing Point.

[The number in line with the temperature of the attached thermometer is to be deducted.]

Temperature of attached thermometer.	Corrections for the barometer at			
	27 inches.	28 inches.	29 inches.	30 inches.
	For each degree above 32 degrees.			
32° to 90°	·0048	·0051	·0052	·0053

The correction for height above sea level may be approximately estimated at ·001 of an inch for each foot of ascent, which is the amount the mercury *falls* as we ascend, and this amount has, therefore, to be added to the readings taken above sea level.

The following table will be found useful :—

Inches of mercury.	29	28·5	28	27·5	27	26·5	26	25·5	25	24·5
Height in feet corresponding.	886	1,340	1,802	2,273	2,753	3,241	3,739	4,246	4,763	5,291
Inches of mercury.	24	23·5	23	22·5	22	21·5	21	20·5	20	
Height in feet corresponding.	5,830	6,380	6,942	7,516	8,103	8,704	9,319	9,948	10,593	

Aneroid barometer.—By the use of the aneroid barometer the necessity for corrections or reductions can be avoided. Its index is set by a standard barometer and it needs no further adjustment. It consists externally of a cylindrical box in which is a thin corrugated metal case from which the air has been exhausted. An increase or diminution of the pressure of the air alters the form of this

case and the movement is communicated by a system of levers to the hands which move over a dial. The range of this instrument is about 10,000 feet and it is sufficiently accurate for ordinary observations.

While the fluctuations in any one place are for the greater part due to a change in the density of the atmosphere above that place, there is what is known as the diurnal wave which has its maximum in the tropics between 10 P.M. and 9–30 A.M. and its minimum between 4 P.M. and 3–30 A.M. Its intensity varies with the latitude. The average intensity is from ·09 to ·12 inch.

Thermometers.—Thermometers are instruments for observing the temperature of the air, and the chief points to be ascertained are the mean temperature, the range and the extremes.

Thermometric scales.—There are three scales in use in different parts of the world. The one in use in British India is the Fahrenheit scale, according to which the temperature of melting ice shows 32° on the scale, and that of boiling water under a barometrical pressure of 30″ as 212°. The Centigrade thermometer used in France and in most scientific laboratories is marked as 0 and 100 at the freezing and boiling points, respectively, while the Reaumur used in Germany, Russia, Spain, &c., indicates 0 at the freezing and 80° at the boiling points respectively.

Conversion from one scale to another.—The following formulæ give the means of converting degrees, Centigrade or Reaumur into degrees, Fahrenheit :—

Let F = number of degrees, Fahrenheit.
R = do. do. Reaumur.
C = do. do. Centigrade.

$$F = \frac{9C}{5} + 32 \qquad F = \frac{9R}{4} + 32 = C + R + 32$$

$$C = \frac{5(F-32)}{9} \qquad R = \frac{4(F-32)}{9}$$

Maximum and minimum thermometers.—At meteorological stations four thermometers are in use, two maximum and two minimum thermometers ; of the two maximum thermometers one is known as the sun maximum, the other as the shade maximum. The former is a thermometer enclosed in a glass case with a blackened bulb ; the case shelters

from currents of air, the black bulb absorbs the sun's rays. The shade maximum thermometer is mercurial, not enclosed in a case. The tubes of these thermometers are contracted in the bulb, so that when the mercury has extended to its fullest extent instead of it all retiring on cooling, it breaks at the narrow portion of the tube, and the instruments are thus self-registering. There are also two minimum thermometers. The shade minimum is an alcoholic thermometer fixed nearly horizontally, but with the bulb slightly lower than the other end. A small needle moves freely within the tube, as the spirit contracts this needle moves down with it but does not return again in expansion. The grass minimum is a thermometer of the same kind, but protected by a glass case; it is placed close to the ground on grass.

Thermometric range.—The range, diurnal, monthly or annual, is the difference between the maximum and minimum indications of the dry bulb thermometers in the day, month or year. The mean monthly range is the sum of the daily ranges divided by the number of the days in the month. The mean annual range is the sum of the mean monthly ranges divided by 12.

Humidity.—The amount of humidity or watery vapour in the air may be determined in various ways, but the method of wet and dry bulb thermometers is the only one which need be referred to. These are two thermometers placed in the shade and the bulbs exposed freely to the air. The wet bulb is covered with muslin which is kept moist by cotton twisted round the bulb and in connection with a vessel of water; the cotton is prepared so that the water may pass up it easily by capillary attraction.

Dew point.—The dew point is that point at which the air is just saturated with moisture, so that the least further fall would cause a deposit of water. Unless the air is saturated, the temperature of the wet bulb thermometer is always above the dew point, but is below the temperature of the dry bulb. If the dry and wet bulbs are of the same temperature, the air is saturated with moisture and the temperature noted is the dew point; if they are not of the same temperature, the dew point is below the wet bulb temperature.

The following table gives the weight of vapour in a cubic foot of air at different temperatures when the air is saturated with moisture:—

Temperature, Fahrenheit.	Weight in grains of a cubic foot of vapour.	Temperature, Fahrenheit.	Weight in grains of a cubic foot of vapour.	Temperature, Fahrenheit.	Weight in grains of a cubic foot of vapour.
°	GRS.	°	GRS.	°	GRS.
32	2·13	55	4·87	78	10·31
33	2·21	56	5·04	79	10·64
34	2·30	57	5·21	80	10·98
35	2·38	58	5·39	81	11·32
36	2·48	59	5·58	82	11·67
37	2·57	60	5·77	83	12·03
38	2·66	61	5·97	84	12·40
39	2·76	62	6·17	85	12·78
40	2·86	63	6·38	86	13·17
41	2·97	64	6·59	87	13·57
42	3·08	65	6·81	88	13·98
43	3·20	66	7·04	89	14·41
44	3·32	67	7·27	90	14·85
45	3·44	68	7·51	91	15·29
46	3·56	69	7·76	92	15·74
47	3·69	70	8·01	93	16·21
48	3·82	71	8·27	94	16·69
49	3·96	72	8·54	95	17·18
50	4·10	73	8·82	96	17·68
51	4·24	74	9·10	97	18·20
52	4·39	75	9·39	98	18·73
53	4·55	76	9·69	99	19·28
54	4·71	77	9·99	100	19·84

Relative humidity.—Relative humidity is a convenient term to express comparative dryness or moisture. If complete saturation be assumed to be 100°, any degree of dryness may be expressed as a percentage of this; on page 41 is a table of relative humidity and is read by taking the temperature of the dry bulb and the difference between it and the wet bulb and by looking in the table at the intersection of two columns.

Cloud formation.—When saturated air is lowered in temperature, its vapour is condensed into extremely minute particles of water constituting cloud or fog. Visible clouds do not seem to be formed at a greater height than five miles above the earth.

Classification of clouds.—Clouds have been classified into three divisions—the cirrus, the cumulus and the stratus. The cirri are streaks or fibres of cloud parallelled or divergent or forming fleecy brush or net-work; they are very

high in the atmosphere. The cumulus is a hemispherical or conical heap like a mountain rising from a horizontal base. The cumulus is formed only during the day, as then only are conditions present which are necessary for its development. This condition is the heating of the atmospheric stratum in contact with the earth which rises and carries off the vapour absorbed during the night. The stratus, as its name implies, is a horizontal sheet of cloud widely extended and continuous, often forming at sunset where the air is calm. There are numerous combinations of these descriptions of clouds such as the cirro-cumulus, the cirro-stratus, the cumulo-stratus, &c., which it is unnecessary here to more than mention.

Cloud estimation.—The estimation of the amount of cloud is by a system of numbers—1 expresses a cloudless sky, 10 a perfectly clouded sky, and the intermediate numbers various degrees of cloudiness. Recently by an instrument known as a sunshine recorder the duration of bright sunshine is measured. It consists of a spherical glass lens through which the sun's rays are focused. The focal point travels along the surface of a card having the hour divisions marked upon it. When the sun shines brightly a line is burnt on the card and from this the length of the duration of bright sunshine is determined.

Indian rains.—Indian rains depend on the prevalence of certain winds. The south-west monsoon is a current of saturated air drawn from the ocean to replace the heated air rising from the Asian plains. It discharges most of its vapours on the West Coast and is comparatively dry on reaching the east. It blows from May to September, and during such times forces back the north-east trade winds until its influence diminishes, when that wind resumes its course, and lifting vapour from the Bay of Bengal furnishes the north-east monsoon.

Conditions causing rain.—The conditions under which rain occurs are those; when air parts with its moisture in solution at a considerable height from the surface of the earth, the minute particles, of which clouds consist, gravitating slowly downwards, tend to aggregate into globules, overcome the resistance of the air and fall as rain. Drops of rain frozen after their formation fall as hail. Snow is probably frozen cloud or from the freezing of the vapour of the cloud into minute particles which afterwards aggregate into flakes.

Table of the relative humidity given by the difference between the dry and wet bulb.

Temperature of the dry bulb.	Difference between the dry and wet bulb.															
	° 0	° 1	° 2	° 3	° 4	° 5	° 6	° 7	° 8	° 9	° 10	° 11	° 12	° 13	° 14	° 15
	Relative humidity, saturation = 100.															
°																
90	100	95	90	85	81	77	73	69	65	62	59	56	53	50	47	44
89	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
88	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
87	100	95	90	85	81	77	73	69	65	61	58	55	52	49	46	43
86	100	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
85	100	95	90	85	80	76	72	68	64	61	58	55	52	49	46	43
84	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	43
83	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
82	100	95	90	85	80	76	72	68	64	60	57	54	51	48	45	42
81	100	95	90	85	80	76	72	68	64	60	56	53	50	47	44	41
80	100	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
79	100	95	90	85	80	75	71	67	63	59	56	53	50	47	44	41
78	100	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
77	100	94	89	84	79	75	71	67	63	59	56	53	50	47	44	41
76	100	94	89	84	79	75	71	67	63	59	55	52	49	46	43	40
75	100	94	89	84	79	74	70	66	62	58	55	52	49	46	43	40
74	100	94	89	84	79	74	70	66	62	58	55	52	48	45	43	40
73	100	94	89	84	79	74	70	66	62	58	54	51	48	45	42	40
72	100	94	89	84	79	74	69	65	61	57	54	51	48	45	42	39
71	100	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
70	100	94	88	83	78	73	69	65	61	57	53	50	47	44	41	38
69	100	94	88	83	78	73	68	64	60	56	53	50	47	44	41	38
68	100	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
67	100	94	88	83	78	73	68	64	60	56	52	49	46	43	40	37
66	100	94	88	83	78	73	68	64	60	56	52	48	45	42	40	37
65	100	94	88	83	78	73	68	63	59	55	51	48	45	42	39	36
64	100	94	88	82	77	72	67	63	59	55	51	48	45	42	39	36
63	100	94	88	82	77	72	67	63	59	55	51	47	44	41	38	35
62	100	94	88	82	77	72	67	62	58	55	50	47	44	41	38	35
61	100	94	88	82	77	72	67	62	58	54	50	47	44	41	38	35
60	100	94	88	82	76	71	66	62	58	54	50	46	43	40	37	34
59	100	94	88	82	76	71	66	61	57	53	49	46	43	40	37	34
58	100	93	87	81	76	71	66	61	57	53	49	46	43	40	37	34
57	100	93	87	81	75	70	65	61	57	53	49	45	42	39	36	33
56	100	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
55	100	93	87	81	75	70	65	60	56	52	48	44	41	38	35	32
54	100	93	86	80	74	69	64	59	55	51	47	43	40	37	34	31
53	100	93	86	80	74	69	64	59	55	51	47	43	39	36	33	30
52	100	93	86	80	74	69	64	59	54	50	46	42	39	36	33	39
51	100	93	86	80	74	68	63	58	54	50	46	42	38	35	32	20
50	100	93	86	80	74	68	63	58	53	49	45	41	37	34	31	29
49	100	93	86	79	73	67	62	57	53	49	45	41	37	34	31	28
48	100	93	86	79	73	67	62	57	52	48	44	40	36	33	30	
47	100	93	86	79	73	67	61	56	51	47	43	39	36	33	30	
46	100	93	86	79	73	67	61	56	51	47	43	39	35	32	29	
45	100	92	85	78	72	66	60	55	50	46	42	38	34	31	28	
44	100	92	84	78	71	65	59	54	49	45	41	37	34	31	28	
43	100	92	84	78	71	65	59	54	49	45	41	37	34	31	28	
42	100	92	84	78	71	66	60	54	49	44	40	36	34	30	27	
41	100	92	84	77	70	64	58	53	48	43	39	35	31	28		
40	100	92	84	77	69	63	57	51	46	42	38	34	31			
39	100	92	84	77	69	63	57	52	47	42	38	34				
38	100	91	83	75	68	62	56	50	45	41	37					
37	100	91	83	75	68	61	55	49	44	39						
36	100	91	82	74	66	59	53	47	42							
35	100	90	80	72												
34	100	89	79	72												
33	100	89	78	70												
32	100	87	75													

Measurement of rainfall.—Rain is estimated in inches, that is to say, that when an inch of rain has fallen on any given area, say a square foot, it implies that rain has fallen equal to one inch in depth. The amount of rainfall is measured by rain gauges, of which there are a great variety, but these are usually in the form of a cylinder which has a funnel-shaped mouth of known area* and which passes the water collected into a inner removable cylinder, whence the water can be readily poured into a graduated glass measure which allows of the depths of inches of fall being accurately read off at once in inches and tenths. The glass measures are graduated in relation to the particular gauge to which they are attached, but a glass can be easily graduated in this way. Suppose the area of the receiving gauge to be 100 square inches, then one inch of rain on this area would be 100 cubic inches; take a glass and pour into it this amount of water and mark the surface level which will represent one inch of rainfall measured by that particular gauge. The distance between this mark and bottom of the glass can be graduated into tenths or hundredths of an inch as may be desired. A gauge which is in an elevated position will indicate less rain than a gauge lower down. This has been said to be due to the effect of the wind, but the cause is probably still to be sought for.

Management of rain gauges.—The following rules are recommended for the management of rain gauges. The gauge should be placed on level ground and so as not to be affected by trees, buildings, &c.; old gauges should not be replaced by new ones until a sufficient time has elapsed to allow of the results of the two sets being compared. The receiving surfaces should be set perfectly level. Heavy falls should be measured as soon after the fall has ceased as possible.

Equivalents of one inch of rainfall.—It is well to notice that an inch of rain on a square yard of surface equals 46·74 lbs. or 4·674 gallons, on an acre 226,225·52 lbs. or 22,622·55 gallons, or 100·9935 tons and on a square mile 144,784,333 lbs., 14,478,433·3 gallons or 64,635·86 tons. But 100 tons per inch per acre is a rough and ready formula to remember.

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* A commonly-used size of funnel is 4·697 inches diameter, $\frac{1}{10}$th of an inch on this gives one fluid ounce of water.

WINDS.

Trade winds.—Air in motion is called wind and is caused by the variation of temperature at different parts of the surface of the globe. Winds except the trade wind, land wind and sea breeze are partial and irregular. The trade winds are surface currents blowing from the polar towards equatorial regions to replace the heated air from the latter. In the northern hemisphere their course is south, in the southern, north. They prevail for 30° on either side of the equator.

Land winds.—The land wind is generated on coasts in the tropics when at night more rapid radiation of heat from the land than from the sea, cools relatively the air in contact with the former, which therefore being heavier passes seaward.

Sea breeze.—The sea breeze is caused by the land absorbing during the day the solar heat more rapidly than the sea; this produces an upward current replaced by a flow of air from the sea.

Cyclones.—Cyclones are rotatory storms generated by the collision of opposing air currents; the centre of a cyclone moves with much less velocity than the wind itself does round that centre. The diameter of rotation varies from 50 to 100 miles. In the northern hemisphere the direction of rotation is  and in the southern  .

Direction of wind, how ascertained.—The direction of wind is determined by a vane. The various points of north, east, south and west should be fixed by a compass taking into account the magnetic variation.

Measurement of velocity of wind.—The velocity of the wind is measured by an anemometer consisting of four hollow cups mounted on two horizontal bars at right angles to each other. The velocity of rotation of these cups is practically one third of that at which the wind moves, and by an arrangement the number of miles travelled is automatically registered. The average velocity of the wind is from 6 to 8 miles per hour. It ranges up to 70 miles per hour rarely, though in hurricanes it has been said to reach 100 miles per hour. The force of the wind is usually reckoned at so many pounds per square foot, and if the velocity is known, the force

can be found from the following table or by the formula $P = \frac{V^2}{2}$, P being the pressure and V the velocity in miles per hour:—

Velocity miles per hour.	Pressure in lb. per sq. foot.	Velocity miles per hour.	Pressure in lb. per sq. foot.	Velocity miles per hour.	Pressure in lb. per sq. foot.
1	0·005	15	1·107	45	9·963
2	0·020	20	1·968	50	12·300
4	0·079	25	3·075	60	17·712
6	0·180	30	4·428	70	24·108
8	0·320	35	6·027	80	31·488
10	0·492	40	7·872	100	49·200

The pressure on a surface which has a direction oblique to that of the wind can be determined by multiplying the force as found above by the sine of the acute angle formed by the direction of the wind and that surface.

CHAPTER II.

PART I.

CONSERVANCY AND SANITATION OF TOWNS AND VILLAGES AS A WHOLE.

INTRODUCTORY.

Sanitary Laws of Moses.—The unwritten laws of sanitation are as old as the appearance of man on the world; but the first written were those of Moses who laid down certain laws for the disposal of excreta; these, though necessarily primitive, have been the key-note of all our modern systems for the disposal of solid waste matters.

Shastras contain no laws relating to removal and disposal of filth.—It is curious to remark that such laws do not seem to have been, at any time, in vogue amongst the Hindus; although the Shastras contain many laws for purifying the body and the household, yet none relating to the removal and disposal of filth find therein a place.

Air of Indian towns impure.—Now while it cannot be denied that Indian towns have been until lately models of what they ought *not* to have been and that the air which the people breathe is still dangerously impure, being contaminated by the poison coming from the soil fouled by the decomposing excreta of the present and past generations, yet it should not be forgotten that London and Edinburgh in the seventeenth century were in a similar disgraceful condition. What, therefore, has been done in Britain can be done in India and this fact ought to be kept in view, viz., that good conservancy and sanitation is the first need of a town. Splendid water-works, fine roads, beautiful lamps, pleasant parks are things much to be desired; but if the soil and foundations of dwellings are saturated with filth, if the air breathed is impure, if we neglect to improve these before wasting money (for waste it would be) on the former objects, severe suffering will be the reward for securing luxuries in place of necessities.

Sanitation to be first directed to poorer parts of a town and parcherries.—No human being can have health in a tainted atmosphere and no atmosphere can be otherwise than tainted where such conditions prevail as do in the poorer parts of Indian towns at present. In these quarters are insanitary conditions most prevalent and no one can walk through these crowded parcherries without feeling that such is the case. To these places therefore in the first instance should vigorous sanitation be directed; it is usually in such places that epidemics begin, and they should, for the good of the general community, be the first care.

Sanitation to be effective requires good supervision.—Sanitation cannot be satisfactory unless there is ample, constant and efficient supervision, and under existing circumstances the chief supervision ought to be exercised by a European. In the lower grades, however, Eurasians or Natives must be depended upon, for, although caste and social prejudices will hardly permit respectable persons to come in contact with scavengers or rubbish and night-soil carts, yet it is found, in Madras at any rate, that a class of Native overseer well suited for the work can be obtained. Hospital Assistants are, from their training, well suited for conservancy supervision.

Faults of overseers.—The great fault of conservancy overseers is inobservancy and they are often negligently blind; the latter fault can be cured by strictness in supervision, the former also, but only by self-training.

Native overseers superior to European overseers.—Native overseers are superior to European, because of their language being that of the people with whom they have to deal; their domiciliary visits are not so much resented as would be those of a European, especially if the overseers be of superior caste. Supervision to be effective must include thorough inspection of houses, back-premises and lanes. Natives are also free from the prejudices and erroneous views which that class of European obtainable at the low salaries usually available, would be likely to hold.

Qualifications of a good overseer.—A good overseer should be a man with great tact and firm temper. He ought, when he knows his duty, to do it without being swayed by promises, threats or abuse. He ought to be observant and methodical and he ought never to be a man of that class who, when asked when a thing is to be done, invariably replies 'நாளைக்கு' (to-morrow).

Good conservancy officers not popular.—A good conservancy officer, if he does his duty thoroughly, is never popular. Sanitary laws *will* inconvenience the public, and of course insistence on their observance will usually give rise to a certain amount of irritation. Against a strict officer petitions will no doubt pour in, and it is therefore well always to bear this fact in mind.

REMOVAL OF WASTE.

Removal of refuse a chief duty.—The removal of waste is one of thec hief duties of a municipality and the regular collection and removal of house and kitchen refuse from the streets and lanes of a village, town or city are necessities.

Waste matters, which must be removed from the neighbourhood of human habitations, may be either solid or liquid, consisting of street sweepings, house sweepings, vegetable and animal food, waste from factories, slaughter-houses and stables, excrement including waste water from cooking and bathing, urine, &c. The amount to be removed by manual labour depends largely on the amount of water-supply in the town and the facilities in the shape of proper drainage works for carrying it off. Thus towns, in which there are no drainage works, but which have cess-pools or similar works, have to provide for the regular emptying of these and the transport of their solid and liquid contents. A town having a limited supply of water will ordinarily require less transport and labour in reference to liquid waste: liquid waste is ordinarily termed sewage and should be removed preferably by means of drains and sewers. Excreta, where the water carriage system has been adopted, is usually disposed of in a similar manner, but in towns where no such system is in force removal by manual labour must be adopted. The cheapness of manual labour has been perhaps one item militating against the march of sanitary progress and the construction of sanitary works in India, for, had labour been as expensive in India as in England, a very different state of matters would have resulted; the monetary objection is probably the strongest factor in the question of sanitary advancement. As it is, some towns have to carry away not only all the solid matters and the excreta, but also a considerable amount of liquid matter, hence there will be found, in the following pages, references to methods of disposal which would find no place in a manual relating to a country in which sanitary works have made proper progress.

Scavenging.—The process of removal of waste is called 'scavenging' or 'scavengering,' and this term is a comprehensive one, including house scavenging or the removal of house refuse, street refuse and the carting away of all materials so obtained. These materials will, in addition to ordinary street and house sweepings, consist of broken plaster, tiles, bricks, bottles, pots, chatties, tins, garden refuse, &c. It is, however, not incumbent on Municipal Councils under present enactments to remove garden and stable or trade refuse, but these matters find their way into the dust-bins, where the system of public dust-bins is in force.

In deciding on the best scheme suited to any particular town, the following points should have attention:—

(1) The manner in which the refuse should be stored pending removal.
(2) The best method of collection.
(3) The ultimate mode of disposal.
(4) The cost.

There are various methods available for collection:—

(1) By storing the refuse in the houses until called for at intermittent periods, the scavengers passing through the streets ringing a bell.

(2) By placing public dust-bins in the streets and requiring householders to deposit all their rubbish in such receptacles, these being cleared from time to time.

This latter plan is the one usually adopted in India, the deposit being allowed at any time of the day or night, the collection taking place morning and evening at which time the streets are also cleansed.

Arguments against deposit in streets.—Now while it does make a town present an untidy appearance to permit the deposit of rubbish in dust-bins at all hours of the day, yet there can be little doubt that, if it has to be stored in the small houses in this country, a greater evil will result; the health of the people would be affected, and of two evils the least should always be chosen; there can be no doubt as to which ought to be accepted when it is a case of health against appearances. The writer is aware that many sanitarians and others are opposed to this view and declare that dust-bins (as they are called in Madras, though garbage box would be a more suitable name) are a nuisance and deserve condemnation; they are said to be often too full and never thoroughly emptied while they emit disgusting odours and become themselves centres of disease.

Arguments in favour of deposit in streets.—As a reply to such criticisms, it may be said that the fault is not in the system of having dust-bins, but because they are not sufficiently numerous nor properly cleaned; similar criticisms might as well be applied to drains or privies, which nevertheless no one would think of condemning on similar grounds. But even with an ample supply of dust-bins, frequently emptied, the untidy appearance will not disappear. Dust-bins, it has been said, are not improving to the morals of the people and various suggestions have been made to decrease this evil as far as possible, one proposal being that it should be arranged that dust-bins adapted for carrying on carts should be deposited in the streets for a space of two hours, the carts then returning and picking them up when full. This would slightly overcome the objection to retention of the matters in the house, but would not avoid it.

Existing practice and effects.—In India unfortunately the people will not take even the trouble to go to a permanently located dust-bin, and a very large amount of the house refuse is deposited in the gutters and drains or just on the side of the street in front of the house (or sometimes the neighbouring house) which produces it. This is of course against law, but habit is often too strong for law and sanitary education is not sufficiently advanced to cause the practice to be decried by the majority of the people themselves. This is a matter for regret, because clean well-swept streets not only add much to the prosperous appearance of a town, but they have a marked effect for good on the morals of their inhabitants. Ill-cleansed and ill-drained streets cause dampness in the houses and vicinity, humidity in the atmosphere and a low standard of health. Dusty streets are injurious to persons inhaling the highly silicate loaded air arising from them and such an atmosphere produces disease even without organic impurities.

Methods of cleansing.—The cleansing of the street surface may be effected wholly by manual labour or partly by machinery; which mode is the more economical depends (1) on the class and condition of the streets themselves, (2) on the cost of labour. Paved streets are more easily cleansed and cost much less to cleanse than, for instance, macadamized roads; the cleansing of a granite paved road in Liverpool costs from 6*s.* to 14*s.* per 10,000 yards, but macadamized roads cost as much as 29*s.*; in a town, therefore, the first cost of a road should be considered not only in relation to the cost of maintenance, but also in regard to the cost of cleansing.

Machinery is more suitable for paved than for macadam roads; even with the use of machinery the stuff collected has to be swept into mounds and carted away in the usual manner.

Removal of rubbish.—The removal of rubbish from Indian streets is usually effected by means of carts drawn by men, bullocks, ponies, or horses; by bullocks, is the more usual plan, though in Calcutta light pony carts are used, and in Madras, during the famine, carts drawn by men were introduced.

Staff required with each cart.—Each cart should have attached to it a driver and at least one sweeper, and if the bullocks are properly trained, the driver is able to clear the rubbish from the dust-bins and the rubbish from the streets which the sweepers, who have preceded him, have collected in little heaps.

Allocation of conservancy staff.—A town, for conservancy purposes, should be divided into distinct areas to each of which a certain conservancy staff should be attached.

Amount of staff dependent on certain circumstances.—The amount of staff will be dependent not only on the population and area, but also on the distance to which the rubbish has to be transported, because, the shorter this distance is, the more trips will the carts be able to make. When the distance to the sites for the deposit of rubbish becomes very great, so that the carts make few or only one trip, it becomes a matter for consideration whether some other means of transport, such as a tramway, should not be adopted. It is a question to be determined solely by the expense of one plan against the other; if a convenient loading station at the tramway can be arranged so that the carts have to travel a short distance, then the staff of carts required can be much decreased, as they can make more trips; if the amount saved by such decrease in staff more than covers the interest, depreciation, maintenance and other expenses in connection with the tramway, then the tramway ought to be adopted. Tramways laid down for passenger traffic can, during the night, be used for the carriage of rubbish, the trains being left in a siding where they would be filled from the carts during the day. Where the method of disposal is by burning, the incinerators can be located much nearer the town than permanent rubbish depôts; the incineration system of disposal will be referred to hereafter.

Methods of working conservancy staff.—There are two methods of working the sectional conservancy staff engaged in clearing rubbish: one is to allot certain carts to certain streets, which they clear in a fixed order, the other to put all the sectional staff in one street, to clear it first, and then to pass on to the next, and so on.

Disadvantages of each method.—A disadvantage of the former system is that, unless there is a peon or maistry in charge of each cart (and it is not usual nor possible on the score of expense to provide one for more than four to five carts), supervision cannot be effective and loitering and shirking work are of frequent recurrence; under the latter system the whole staff can be under the eye of one man, the cleansing more effectually executed, but some parts of the section will not be cleaned until a late hour in the day. This inconvenience may be lessened by the work being commenced at a different part of each section daily. The inconvenience will also occur under the former system, but then it is minimised.

Carts for liquid filth.—Where there are open or ditch drains and cess-pools, a second set of carts will be required to remove liquid matters; these carts ought to be covered and water-tight and they should be worked under conditions similar to those already referred to.

Contract *v.* Departmental labour.—Another point which should be considered carefully is whether the cleansing of a town ought to be by contract or by departmental labour. This is to be looked at not only from the financial side of the question, because efficiency should be a prominent consideration. The writer's experience is, that the cleansing of towns cannot be carried out satisfactorily by contract. If payment is made on the basis of so much per man and per pair of bullocks and cart, or on a time basis, it is not the interest of the contractor to overwork, or even fully work, his people. The better plan would evidently be payment for the number of full loads delivered at each depôt, but here again the contractor would naturally try and fill his carts at the nearest site. A combination of these two plans might be more satisfactory, but in no case does the writer think it would be fully so.

That departmental labour would cost more than contract labour there can be little doubt, but the question is really a question of effective cleansing and not one of cost. Evils there will be under both systems and it behoves each

municipal council carefully to consider the *pros* and *cons* of the question as affecting its own particular town.

The following table gives the cost of street cleansing in certain important towns in England and India :—

——	Annual cost.	Per 1,000 population.	Per mile of street.
	£	£ s. d.	£ s. d.
Bedford	900	45 0 0	45 9 0
Carlisle	2,261	64 6 0	113 0 0
Oxford	2,750	63 9 0	85 9 0
Liverpool	82,284	151 2 0	316 2 0
Swansea	4,200	60 0 0	76 3 0
Calcutta	Rx. 79,250	Rx. 116 0 0	Rx. 430 0 0
Bombay	Rx. 52,063	Rx. 67 0 0	Rx. 290 0 0
Madras	Rx. 39,006	Rx. 86 0 0	Rx. 83 0 0

The cost depends greatly on the distance the carts have to travel to the depôts or the fact of the town being scattered or closely built, and also on the size of the town, because if, of large extent, the distance of central portions from possible depôts is great.

Manner of disposal of rubbish.—The Municipal Acts contain the following provisions regarding the deposit of rubbish, filth, dust, ashes, &c. :—

"The President (or Municipal council) shall provide, in convenient sites, suitable and sufficient depôts or places for the deposit of the matters mentioned in this section, and shall give notice of such provision."

The universal method, until lately, for the disposal of town refuse in this country was by throwing it into pits, tanks, ponds and low grounds. There are many objections to the practice, but if the rubbish is dry rubbish and kept dry, though it can never be made unoffensive, it may be prevented becoming a producer of disease. Although a town may be properly sewered, provided with latrines and with a separate system for the removal of night-soil, yet night-soil will be present in the rubbish and all rubbish ought therefore to be well and quickly covered after it is deposited. It is usual in some municipalities to let out the rubbish depôts on contract annually, but there is no doubt that great restrictions ought to be imposed when such sales take place. The excavation of even old rubbish depôts may produce cholera

from the germs present in the rubbish, and it should therefore be required that no rubbish shall be touched until it is at least seven years old; in Madras even that period has been found insufficient for thorough disintegration. When the rubbish is mixed well with lime, it can be sold in a much fresher state, if it is to be at once used to manure fields or mixed with sludge and ploughed into land. Another possible method of disposal for towns on sea coasts or navigable rivers is to carry the rubbish out to sea in hopper barges.

Rubbish ought not to be deposited in tanks with water in them.—Rubbish ought not, as a rule, to be deposited in tanks in which there is water, nor in tanks into which water may come before they are completely filled up; in the latter case where the filling of such a tank is desirable a wall of mud ought to be built across the tank cutting off so much of it as can assuredly be filled before the rains; the second portion of the maxim is thus complied with. All tanks in which it is intended to deposit rubbish ought to be pumped out dry before the work is commenced. The earth for covering the rubbish (and over all rubbish there ought to be a covering of not less than 6 inches thick) may be obtained from the bottom of the tank just in front of the rubbish as tipped.

Sinkage of rubbish after decay.—When a hollow or tank is being filled with rubbish, the rubbish must be piled much higher than the surface of the surrounding ground. It is found in England that after a few months' exposure to sun and rain the rubbish shrinks 12 per cent.; and in India it shrinks 16 to 20 per cent., the rubbish ought therefore to be piled one-sixth to one-fifth of its depth above the surrounding ground.

Depôt sites.—The sites of the depôts, while as near the town as possible, should be in such positions as will necessitate the carts passing through the town as short a distance as possible and the sites should be readily available to customers; they should however be so far from roads, lanes and houses as not to cause a nuisance and the direction of the prevailing winds should be taken into account.

Deodorization of rubbish depôts by cultivation.—There is no better plan of deodorizing rubbish depôts than by cultivation of their surface; the growth of weeds may therefore be freely encouraged. After a year or so, the land

may be ploughed and a crop of cholum or other hardy crop raised from it. In Madras, and the writer is not aware that the plan is greatly in vogue elsewhere, it is a common practice to use such raised lands as sewage farms; they act admirably as such owing to the porous nature of the soil so formed. Sewage farming will be referred to later on in connection with drainage.

Suggestions in regard to tank filling.—In addition to the foregoing remarks, the following suggestions in regard to tank filling, framed by R. C. Sterndale, Esq., Vice-Chairman of the Municipality of the suburbs of Calcutta for the use of that Municipality, may be quoted; these rules met with the approval of the Bengal Government:—

"*The filling up of existing holes, pits and low swampy lands.*

"Here the municipality may come forward and help landlord and tenants, and in order to do so effectually, I have to propose the following arrangements for filling small holes and pits and raising low swampy lands within bustees and other parts of the township for the mutual advantage of the Municipality and the rate-payers. At present not only does the Municipality make nothing by the sale of town sweepings, but it is often put to some difficulty to find convenient places of deposit for them so that the carts have often to travel considerable distances to dispose of their loads and thus waste time.

"One of the objections to the disposal of sweepings within the town is the difficulty of getting earth to cover the deposit. This can only be met by having earth dug beforehand from the spot where the sweepings are to be thrown. This at first sight would appear somewhat useless waste of labour, or somewhat like the Irishman's effort to lengthen his blanket by cutting a piece off the bottom to sew it on to the top; but when it is considered that a trench 40′ × 5′ × 5′ will give 1,000 cubic feet of earth equal to a surface area of 1,000 feet, if spread one foot thick, it will be seen that the plan can be advantageously carried out. Then supposing we have a tank of, say, 100 feet long by 60 feet wide and average depth of 12 feet to fill up, it would be necessary to cut a trench 10 feet wide by 3 feet deep all round the tank, as 320 × 10 × 3 which will give 9,600 cubic feet of earth sufficient to cover the area of tank and excavation one foot in depth while 100,000 cubic feet of rubbish, allowing about 25 per cent. for settling, will be required to fill the tank.

"As the owner of the land would be a very considerable gainer in the improvement of his property, the Municipality might fairly charge him, say, Rs. 100, or about Rs. 16 per 1,000 feet of surface reclaimed. I would make this charge

where the tank was over 8, and not exceeding 12 feet in depth, but where less than 8 feet, I would lower the charge to Rs. 10 per 1,000 superficial feet.

"The charges should, in all cases, be made in advance.

"The work of excavation, levelling and dressing should be done by the establishment coolies in the afternoon, under the supervision of the overseers, and should be paid for as overtime work at regular earthwork rates, the overseers, jemadars, and peons being paid a percentage of the amount in proportion to their respective salaries. In order to stimulate the cartmen to work quickly, I would propose to pay them a small sum, say, one pie per cart-load deposited, a regular tally being kept.

"The advantage to the Municipality would be the more expeditious and complete cleansing of streets, the removal of refuse from courts and by-lanes where it now often lies untouched, the increased healthiness of the town resulting from this and from the suppression of so many sources of malaria, the increased value of taxable property and the general benefit to the ratepayers in having filthy holes and ponds reclaimed at a reasonable cost, the lands now profitless, made available for tenants or building purposes.

"The value of the sweepings may be put out of the question at present, as they are now of little or no profit.

"The advantages gained may be summed up—

(1) A large number of malaria, fever, and cholera centres are obliterated from the map.

(2) A source of danger to children and even adults is removed from the heart of the bustees and the sides of the highways and thoroughfares.

(3) Valuable sites for either building, trade, or cultivation purposes are acquired at small cost.

(4) The Municipality has facility for disposing of the street refuse without the expense of a long lead.

(5) A considerable amount of assessable property and consequent increased rates is acquired.

"In the suburbs an area of one hundred and sixty biggahs or over 54 acres of land has thus been reclaimed, the value of which would not be less than Rs. 2,00,000 (two lakhs of rupees).

"Where lands have been reclaimed in the manner above related, the local authority should place a decided veto against their being used as building sites or bustee settlement for at least four to five years, during which interval they may be used as grazing ground, gardens or plantations. After four or five seasons' cultivation they may safely be built upon by huts or light structures which will not require deep excavations to put in foundations. The local authorities in Bengal have ample powers under the Bengal Municipal Acts to control settlement on such lands, and this is a matter that should be insisted upon in all cases."

Carbonization of rubbish.—Though the ordinary method of rubbish disposal is by sale for use as manure or by filling it into low places and then covering it, the plan of burning or carbonization is coming more and more into use. The towns of Calcutta and Bombay now burn a large portion of their rubbish and Madras is considering the adoption of the system. The main expense is the cost of the construction of the incinerators, for, after these are built and the fires once lighted, the rubbish should be burnt without any other fuel than itself being used. Against the first cost may be set the savings which will result in the less distance carts would require to travel, as the incinerators, if properly constructed, can be located almost in the centre of the districts producing the rubbish.

Again the products of incineration are valuable and steam can be produced at a negligible cost which can be used for driving machinery for various purposes in connection with conservancy or otherwise. The composition of rubbish varies very greatly in different countries and towns, and in England there is a large amount of incombustible matter found in it; this to some extent will be found in India. The cost of any process for disposal is the price paid for securing purity of soil and air and any proceeds must be set against the price of scavenging.

The following are the principal points to be aimed at in the construction of a 'refuse destructor' or 'incinerator':—

(1) Means of easy access by carts to the tipping platform.
(2) Easy and expeditious means of charging the furnaces.
(3) Perfect and complete combustion without nuisance, such as the emission of dust, smoke or unconsumed gases.
(4) The reduction of the material to as small a bulk as possible.
(5) Speedy combustion.
(6) Limited labour in connection with them, thus the cells should be easily charged and cleared.
(7) The obtaining and utilization of as much heat as possible.

Many destructors have been designed and are in use; the one finding at present most favour in England is known as the 'Perfectus,' while Robert's and those of Garlick and Christiansen's are probably the best and most suitable for India; a sketch of the Robert's destructor is given, (*vide*, plate).

ROBERT'S PATENT
TWIN CELL DESTRUCTOR

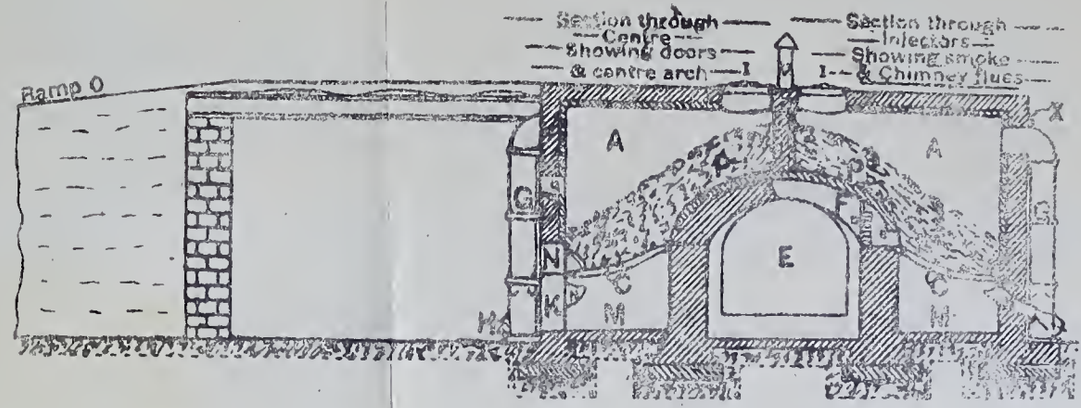


Fig 1

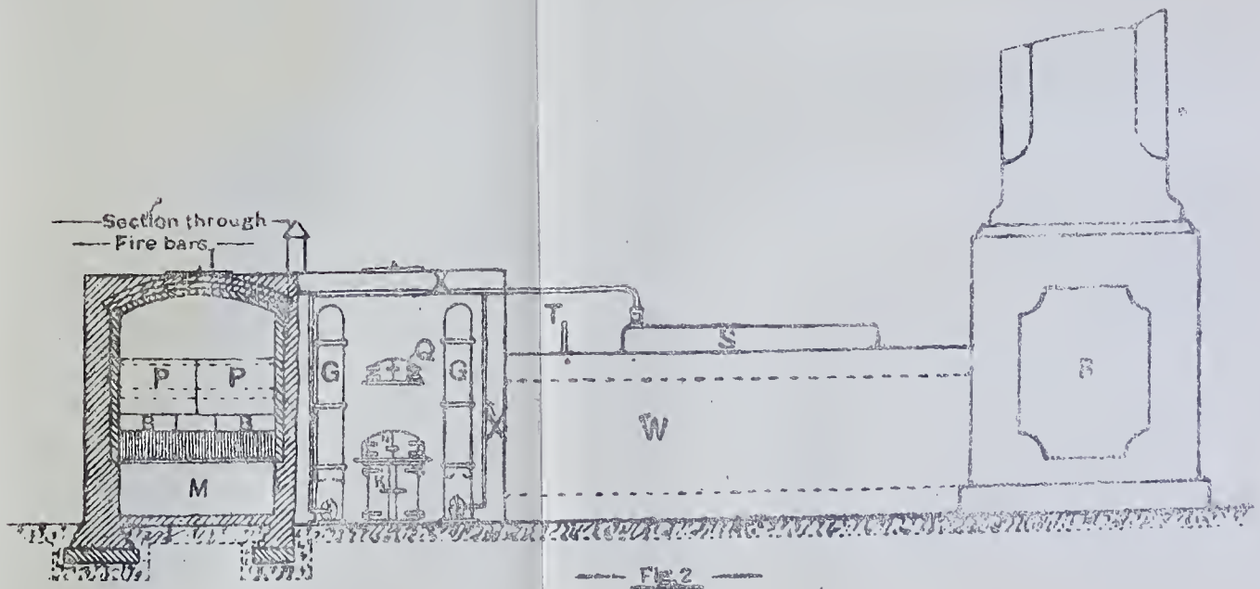
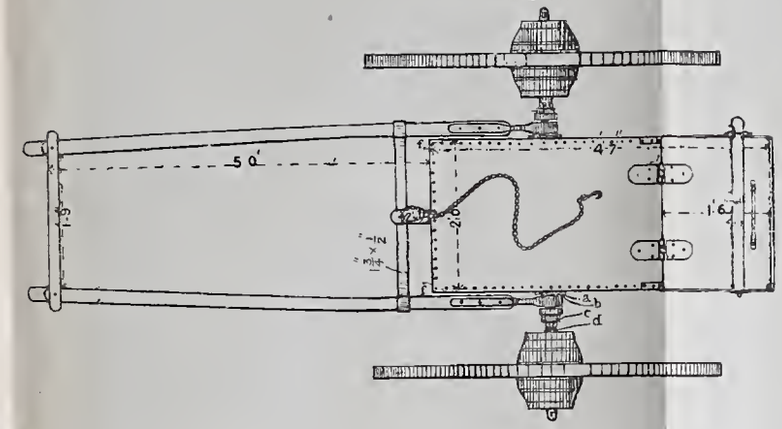


Fig 2

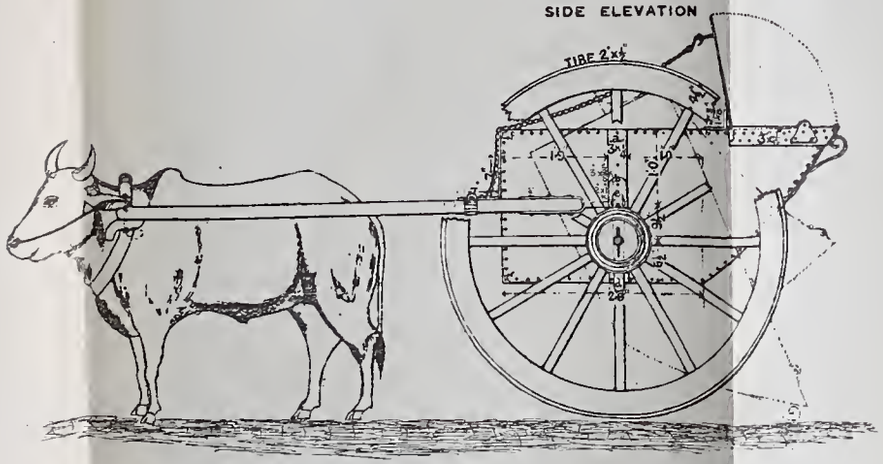
Register No. 2285
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Photo-Zinco., Survey Office, Madras.
1896

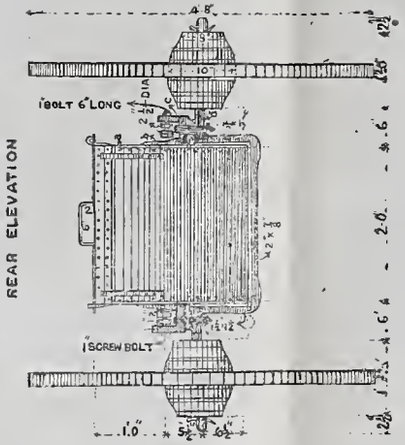
PLAN



SIDE ELEVATION



REG. No. 2495
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DESIGN FOR AN

IRON.

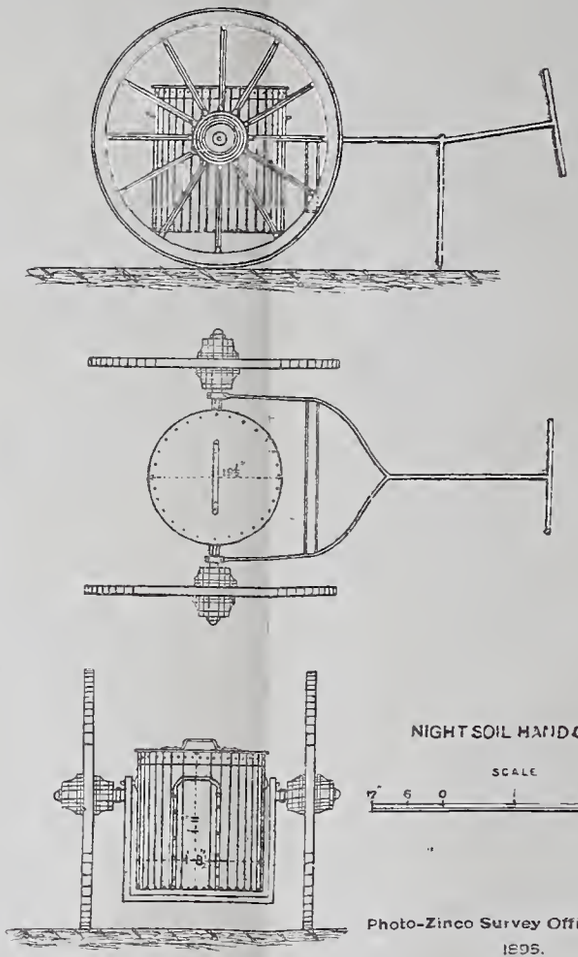
— WATER-TIGHT —

— CONSERVANCY CART —

— SCALE —

INCHES 2 9 6 3 0 1 2 3 FEET

— REFERENCE —	
WROUGHT IRON PLATES	⅜" THICK
ANGLE IRONS	2½"x2½"x⅜"
RIVETS	⅝" DIAMETER



NIGHT SOIL HAND CART

SCALE

7 6 0 1 2 3 FEET

Photo-Zinco Survey Office, Madras.
1895.

The following is Robert's description of his patent twin and single cell refuse destructors :—

Figure 1 shows a sectional end view of Robert's Patent Refuse Destructor, the cell on the right being a section through the injector and smoke flue, and the cell on the left section through the fire-doors and ash-pit door showing centre-supporting wall of main flue covering.

Figure 2 shows two twin destructors side by side, one being a section through the fire-bars and the other a front view showing arrangement of smoke flues, fire-doors, and injectors, also main flue boiler, and chimney. The following lettering refers to both views :—A is the furnace, which is built in such a way as to prevent the passage of any unconsumed gases into the chimney, this being accomplished by closing the usual opening for the escape of smoke above the fire and substituting therefor openings B near the fire-bars, where the fire is brightest, and where only the consumed gases can be drawn off ; C are the fire-bars of special shape with large air spaces between them ; Y is a row of bars at fire-door end of grate to admit air to the material at the end ; P is the drying shelf on top of main flue E leading into chimney ; D is a perforated fire-block, and F inlet for air from the opening V on top ; the smoke flues G collect the smoke and unconsumed gases generated by the fire, which cannot be discharged into the chimney flue E, and the injector H is for supplying an artificial current of air to the furnace and for sucking in the smoke and gases from the smoke flue G. The injector is so constructed that one end is open to the outside air and the other open to the fire-bars C, while it has a further opening in its centre which opens to the smoke flue G. The injectors are of sufficient size and number to give an ample supply of air to the fire, and also to draw in the smoke and gases from the flues G. They are also provided with a regulator, so that the quantity of air and unconsumed gases injected can be regulated, for instance, by closing the supply of air to the injector, the air and gases in the cell can be made to circulate through and through the material in course of combustion, and by opening the air inlet to injector and closing the flue G only fresh air would be admitted to the fire which would pass through the chimney ; by this means the furnace can be regulated for burning any material. All the flues are provided with doors for cleaning ; I is an opening on top of each cell, with close-fitting cover for filling the furnace ; N is the fire-door near the fire-bars, through

which any clinkers are raked out; Q is an opening above the fire-door for drawing the dried material from off shelf P on to the fire; M is the ash-pit; X steam pipes from boiler S to injector H; the heat passing through the boiler to chimney R is regulated by two dampers T, so arranged that, when the damper to boiler is open, the one in the flue W is closed; O is the ramp, leading up to destructors from the road, and is connected to the destructor by an iron or brick bridge.

The mode of action is as follows :—

The carts containing the refuse are driven up the ramp O, the feed-hole cover I is removed, and the refuse tipped from the cart into the destructor and the cover I replaced. The refuse entering the destructor falls upon the shelf P built over the main flue, where it is dried. As the refuse on the fire-bars C is consumed, the clinkers and other non-combustible materials are drawn out through the fire-door N, the fire stirred up, and fresh material from shelf P drawn down on to the fire using open Q. The unconsumed gases in the form of smoke, &c., generated in the upper part of the furnace, collect in the smoke flues G, and are conducted into the injector H, where they are injected by a steam jet with a mixture of fresh air at a high temperature under the fire-bars C, and having to pass through and be exposed to the hottest part of the fire, where the fuel is incandescent on the way to the chimney flue E, all the unconsumed gases will be consumed with any particle of carbon suspended therein, and only the vitiated air and consumed gases are carried up the chimney flue E. The gases, while being consumed and passing through the openings B, are supplied with heated fresh air through opening F. Paper and other materials are prevented from being drawn into the flue E by the perforated firebrick D.

This destructor is similar in design to the twin cell destructor but arranged for natural draught. The air inlet F at flue end of fire-bars draws its supply of air from opening V at side of furnace instead of on top, as in the twin cell. As the air and unconsumed gases are not forced in by a steam jet as in the twin cell destructor, the action is as follows in this case: The draught produced by the heat of the fire passing up the chimney causes a rush of air through the injectors, as they are the only means by which air can enter. The air rushing through the injector sucks in the unconsumed gases from flues G and mixes

therewith at a high temperature. This mixture is then drawn through the bright part of the fire and mixing with the air admitted through opening F is completely consumed. Forced draught can be applied to this also, and where straw and other light material is burnt, which does not produce a solid incandescent fire, a small supplementary boiler with coal or wood fuel should be used, but where cinders and large heat-producing material is burnt, a small multitubular boiler can be fixed in the flues. The flues and chimney can be built large enough to allow of another cell being added.

The chimney can be entirely of brick, or an iron chimney can be fixed on a brick base.

Robert's destructor (single cell) has been erected and is in use at Howrah with the following results :—

The cost was Rs. 1,000. *
It burns 6 to 7 cart loads daily of 40 cubic feet each.
The cost per month is only Rs. 8.
The refuse after destruction amounted to 12 per cent. of cinders and a small quantity of clinkers.

Garlick's and Christiansen's incinerator has been tried on a larger scale in Bombay and the following are the results obtained by the Engineer of the corporation :—

Three furnaces consumed,	93 cart loads, or 46½ tons per diem,	wet weather.
	132 cart loads, or 66 tons,	dry weather.

The temperature in the furnaces exceeded	1,500° F.
The ash produced by incinerator was ..	9 per cent.
If the furnaces were worked day and night the cost of staff, coal (12 tons), and oil per month would be	Rs. 700
The quantity (average) would be per month	.. Carts 3,300
The average cost per cart would be	.. Rs. 0-2-5

The cost of working in England has been found to vary very much as do the quantities burnt.

The quantities burnt vary per cell from	4 to 10 tons.
The cost per ton from	3*d.* to 3*s.* 6*d.*
The cost of repairs on capital expended	1 to 20 per cent.

* This is much less than the usual cost, *vide* page 60.

The cost varies because of the great difference of the composition of the rubbish collected in one town and another, thus one town has paved streets, another macadam: one has water sewage, another the pail system.

The average cost of incinerators in England per cell is £525, say	Rs.	10,000
The average number of men employed per cell		1·17
The average annual cost per cell £96, say.	Rs.	1,800
The average height of chimney	Feet	163
The average cost of destruction per ton 11½*d.*, say	Re.	1

The cost of one cell of Robert's destructor will be from Rs. 2,500 to Rs. 3,000; this does not include the cost of the chimney, which does for a battery of cells, and varies with the height necessary.

Against these charges, as the incinerator can be placed within the area whence refuse is collected, there is the saving to be effected by the reduction of the number of carts, bullocks, &c., and the staff employed at the rubbish depôts.

COLLECTION, REMOVAL AND DISPOSAL OF EXCRETA.

Collection, removal, and disposal of excreta.—The collection, removal and disposal of excreta has not as yet been referred to, but it is no less an important part of sanitation than the collection of rubbish, garbage, and other such matters, and no branch of sanitation has, of late years, been the cause of more discussion.

Energetic measures for disposal necessary.—When men collect in communities, the disposal of excreta is literally a matter of life and death, and before it can be settled the utmost skill and energy of a people may be taxed (Parkes).

Aspects in which the question may be considered.—The question is one which may be considered in many aspects, sanitary, agricultural and financial, and in all of these are municipalities interested.

Collection should be separate from rubbish.—There is no doubt that the collection of excreta should be made separately from that of street sweepings and rubbish, and for many reasons, the carts should be air-tight and such carts would be unsuitable for rubbish; to prevent

nuisance, the collection must be made at early hours of the morning or during the night; the disposal of night-soil requires more care and attention than that of rubbish.

The following clauses are to be found in the City of Madras Municipal Act:—

"The President shall provide suitable and sufficient covered vehicles, carts or other means for the separate removal of night-soil and other offensive matter from the houses in all parts of the city which the Governor in Council shall, by notification, declare to be subject to the provisions of this clause, and the President shall give notice of such provision.

"Whoever deposits any night-soil or offensive matter, after such notice in any dust-bin or in any vehicle, cart or vessel not covered, or in any municipal cart not intended for that purpose, or before or after such notice in any of the places mentioned in clause 2, section 307, or in any manner otherwise than directed, shall be liable to a fine not exceeding Rs. 10 for each offence.

"Whoever, after such notice, deposits any matter other than night-soil or other offensive matter in any vehicle, cart or vessel provided under this section for the separate removal of night-soil and other offensive matters, shall be liable to a fine not exceeding Rs. 10 for each offence, but no person shall be liable to such fine by reason of mixing dry-earth or ashes with night-soil or other offensive matter in the manner of a deodorant."

Rapidity and regularity of removal primarily necessary.—The primary sanitary object is to remove regularly and rapidly the excreta from private dwellings and public latrines. In England, under various systems, the excreta is removed only once a week, but in India, where decomposition is much more rapid, removal once a day is imperative.

Methods of removal.—The usual methods of removal of excreta are those employed in water carriage, the dry-earth system, ordinary bucket system, and pail system.

Removal by water carriage.—Where an underground sewage system exists which allows of the disposal of excrementitious matters by water carriage, the method of removal has got past the stage of useful discussion, but in the majority of Indian towns and villages such a system is rarely to be found. The advantages of such a system as well as its objectionable features will be pointed out when dealing with the question of sewerage and drainage; the systems of removal of excreta now to be considered are those which are applied where no drainage works find a place.

Moule's system.—The dry-earth system, due to the Rev. Mr. Moule, is not new; its essential principle is that of the law laid down by Moses which has been already referred to. Dry-earth is a great deodorizer of foul matters, as a given quantity will destroy or prevent the escape of all poisonous odours. The difficulty in the application of this system is the large quantity of dry-earth required, certainly not less than $2\frac{1}{2}$ lbs. per person a day, and this amounts to about 408 tons per 1,000. people per annum; this is for fluid as well as solid excrement. There is also the difficulty of procuring and storing dry-earth, especially during wet weather. These difficulties and the attendant expense preclude the general adoption of this system which, however, can be applied in special cases.

By the addition of the above quantity of dry-earth the excrement will remain inoffensive for two to three months. It appears that a certain disintegration of fæcal matters and a combination between earth and organic matters contained in the excrement take place. After a time no excremental matter whatever can be detected in the mixture; less earth than the above quantity is insufficient, more is useless.

Certain earths are better than others for deodorization and they may be classified in the following order:—(1) Rich garden mould, (2) Petty soils, (3) Black cotton soils, (4) Clays, (5) Stiff clayey loams, (6) Red ferruginous loams, (7) Sandy loams and (8) Sand.

The advantages of the dry-earth system are, that by its use, both the liquid and solid excreta can be received and rendered easily removable without offence or loss of value as manure, that the action of the earth on the excreta is immediate, all fermentation being prevented, and that the absorption and deodorization of the excreta result in preventing infection.

Owing to the large amount of earth which is required to be carried into a town and out again, the system is a very expensive one and while it may very properly be applied to jails, hospitals or public latrines, it is not well suited for large centres of population and, indeed, if a daily removal system is in force, it is not a positive necessity; it should, however, be adopted in all cases of infectious disease even though other deodorants and disinfectants be used.

Again in India closets are not used as a rule by the great body of the people as in England except probably in the case of public latrines, but even these, in many instances,

are not of a design to which the dry-earth system can be applied.

Bucket system.—The ordinary bucket system is perhaps, the most suitable to India when the collection takes place daily. In Bombay, this system is known as the Halalcore system, and there is a special assessment levied for the duties entailed. There are gangs of scavengers each of which have from 30 to 40 houses allotted to them. These men visit the houses daily and remove the contents of the privy daily in a closed wooden or zinc bucket to central depôts, where the filth is collected in air-tight carts and carried beyond the town or discharged into the sewers at places provided for that purpose.

Madras bucket system as applied to densely populated localities.—In the more populated districts of the city of Madras a somewhat similar plan is in vogue, but the sweepers do not enter the houses. A certain number of streets are allotted to the sweepers. These men, at certain hours of the morning, 6 to 8 A.M., pass through the streets with a bucket mounted on wheels and into these, as the men pass, are emptied the privy contents by the sweepers belonging to the various houses. When a bucket is filled, the sweeper wheels his bucket to what are called 'Trolly stations.' At these places are stationed trollies or carts (*vide* plate) each of which carry eight of these buckets, and here the sweeper exchanges a full for an empty bucket and returns to his beat. Each trolly serves a small area of the city and when it has received eight buckets full it goes direct to the night-soil depôt or to a canal wharf, where from 80 to 140 buckets are loaded on board a boat which carries them many miles along the canal to the night-soil depôts where the night-soil is buried and afterwards disposed of.

Madras system as applied to suburban parts of the city.—In the less thickly populated and suburban divisions of Madras, the inhabitants are required to provide themselves with buckets of a capacity suited to the size of their household. Into these buckets must be thrown all soil and animal matter, and the buckets remain in a screened position and ready between 12 (mid) and 6 A.M., for emptying.

Amount of excreta to be collected.—A matter for determination in each particular town is the amount of solid and fluid matters which ought to be collected. The

production of fæcal matters has been estimated per person as follows * :—

——	Adult.	Average.
Solids per diem ... ... lb.	·33	0·24
Fluids do. ... ... lbs.	2·53	1·51
Solids per annum ... ... „	121·18	87·60
Fluids do. ... ... „	935·64	542·40
Solids do. ... ... c. ft.	1·92	1·40
Fluids do. ... ... „	14·85	8·60

Circumstances tending to vary amount.—The nature of the food will influence the quantities of solid and fluid matters, and the amount of matter to be carried away will greatly depend on whether the urine runs off by drains or remains in the latrines or cess-pools.

Ultimate disposal.—The consideration of the ultimate disposal of excreta brings forward the agricultural and financial part of the question.

Human excrement, a valuable manure.—It is well known that human excrement is a most valuable manure; the annual produce of an average individual of the four principal useful components is as follows :—

——	Fæces.	Urine.	Total.	Value.
	LBS.	LBS.	LBS.	RS.
Ammonia	1·49	9·38	10·87	5
Phosphate of lime	2·00	2·80	4·80	1·2
Potash	0·25	1·08	1·33	0·33
Organic substance	10·51	22·49	33·00	0·33
	14·25	35·75	50·00	6·86

Excrement compared with guano.—A quantity of human excrement, if reduced by evaporation to the condition of dry guano, would contain about $2\frac{1}{2}$ times the amount of ammonia which the same quantity of guano does, and it is thus a most valuable fertilizing manure.

Excreta valuable if properly collected.—At present there is no known system of disposal of excrementitious

* These are from European tables. MacNally says that the quantity of ordure from a mixed Indian population is about $7\frac{1}{2}$ oz. per head daily and of urine $1\frac{3}{4}$ pints or including ablution water $2\frac{1}{2}$ pints.

matters from towns which can be called a commercial success, but, if excreta is collected and disposed of in a proper manner, it is a property which will give a not inconsiderable return. It is necessary that excreta should be removed in as pure a state as possible, for, if it be mixed with quantities of sand or other such substances, it becomes unfitted for application to land or for the manufacture of poudrette.

Method of application of night-soil to the soil.—Night-soil, when collected, can be either applied directly to the soil or it may be formed into poudrette or buried in pits which is the cheaper method. Direct application to the soil may be effected by mixing the excreta with a little town refuse and then distributing it over the land, digging it in at the roots of trees or in trenches such as are in betel or plantain topes. This system is objectionable in populated localities; it is a system much in use in China where prejudices against the use of excretal matter are unknown and where every yard of soil is cultivated and every individual tree manured.

Manufacture of poudrette.—The manufacture of poudrette consists of the treatment of the excreta with fine ashes, carbonized rubbish, &c., which are stored in shallow trenches and into which the excreta is poured on arrival. The material is then allowed to dry, or dried artificially.

The following is a description of the Poona method of disposal called the sun-drying process:—

The street and house refuse collected from the dust-bins of the city are carted out and burnt into ashes. Beds are formed with floors made of *murum* or other hard substance to receive the night-soil. The beds are eighteen feet square and one foot deep. A layer of ashes, one inch thick, is first spread over the floor of the beds, and night-soil is then poured on about five inches deep and is covered over with another layer of ashes, also one inch thick. It is then allowed to remain for twenty-four hours in the sun during the fair season, and for three days under sheds during the rainy season. The night-soil is, after the lapse of time mentioned above, stirred and well mixed with the ashes spread above and below it, and a fresh layer of the latter, half an inch thick, put on, when it is allowed to lie for three days further in the fair season and eight days during the rains. The mixture is then again stirred, taken out of the beds and spread on dry open ground exposed to the sun, to complete its drying. It is then stored in heaps for sale and is in dry weather fit for immediate use. In the rainy season the drying has occasionally to be done under cover, and consequently the process occupies as many as twelve days, whereas in the cold season it takes six and in the hot season only four days.

It is said that the manure thus prepared is so much appreciated by cultivators that payment is frequently made four to six months in advance to secure a supply.

The financial result is certainly encouraging, the total cost having been Rs. 18,000 and the receipts Rs. 5,000 per annum. The actual cost of removing the filth from the town, an unavoidable charge it must be borne in mind, was Rs. 14,400, so that the net profit on the actual expense of manufacture, viz., Rs. 3,600, was Rs. 1,400, or nearly 39 per cent.

Burial of soil in trenches.—Burial in trenches is an extremely convenient process where a sufficient area of dry land can be obtained apart from dwellings, but is advisable that the area should be equal to the demands of the town or portion of the town to be served by it for a period of eight years. The trenches should be 2 to 3 feet broad, 3 feet deep and with 2 feet between each trench. The trenches ought not to be filled more than 2 feet deep. At the end of the seventh year the first year's soil may then be sold and next year the second year's, &c. Under such a system the chance of causing the germination of disease would be extremely small, as the soil would then be in such a condition as would allow of its transportation without offence.

A system adopted by the Calcutta Suburban Municipality, consisted in deep and close trenching in garden grounds with annual removal, and as in some instances a sufficient area of land may not be obtainable to allow of the adoption of the system above advocated, a description of the results of that system may be found useful.

1*st*.—Ground used for the burial of night-soil in the month of April was opened up in the beginning of November following. To a depth of two feet from the surface the soil was ordinary stiff alluvial earth; the next or night-soil layer consisted of a loose rich, black mould, without any offensive smell or any trace of fæcal matter, quite fit for garden purposes. After a few days' exposure to light and air, it was undistinguishable from the surface soil.

2*nd*.—Trenches used in May were dug up, the night-soil layer being a bluish black mould, free from any smell or appearance of fæcal matter.

3*rd*.—Trenches used in June and July were not sensibly different from the last, except that traces of fæcal matter, chiefly fibrous, were visible throughout the mass.

4*th*.—Trenches used in August were somewhat offensive when opened and fæcal matter was found in masses still unconverted.

5*th*.—The trenches recently filled in November were perfectly inoffensive, until the layer of night-soil was exposed by the

spade, when an offensive odour was perceptible close to the trench. But the mass was perceptibly undergoing a change.

Every effort is made to mix the soil with earth as dry as possible when the trenches are being filled and the last eighteen inches is filled up with earth alone.

Revenue derivable by sale of night-soil.—A considerable profit is very often derived from the sale of night-soil. Antwerp obtains £2,700 per annum, Ostend £700, Stockholm £2,000, and Nottingham £2,000. The cost of scavengering at Poona is Rs. 18,000 annually, and Rs. 5,000 are obtained from the product of the sun-drying process. Sir E. C. Buck has said that Rs. 25,000 per annum has been obtained from the sale of night-soil per annum at Farukhabad. In Madras the amount realized annually by sale of night-soil from one depôt, where the excrement of 124,000 people are deposited, is Rs. 4,000. The night-soil is eagerly bought by cultivators of the lands outside the city, who have already found out what valuable manure it is. Much of the Madras night-soil, however, is delivered mixed with sand from the open latrines of the city, and this consequently deteriorates its value.

PLANT FOR REMOVAL OF WASTE.

Carts, &c.

As previously stated, the actual sweeping of the streets may be effected by hand or machinery.

In England the sweeping by manual labour is effected by bass brooms which are considered better than birch brooms; of whatever material formed the brooms should be sufficiently stout of regular length and somewhat elastic and not dry.

When machinery is employed the machine consists of rotary brushes fixed in a frame and usually drawn by one horse. An ordinary size of machine clears a width of 6 feet, the brush or portions into which it is divided works diagonally clearing itself of mud or dust as it progresses. It can probably sweep 15,000 square yards of road per hour equal to the work of 50 ordinary Englishmen.

These machines cost £30 each and cost little for repair except the brushes which cost £2–15–0 a set and they last for about 180 hours work.

The ridge of sweepings left by the machine is swept into heaps and put into carts to be taken away in the ordinary manner.

The amount of plant requisite to efficiently carry out the removal of rubbish is a matter of somewhat difficult estimation and must be determined by local conditions.

These conditions are—

(1) The production of rubbish per head.
(2) The capacity of the carts.
(3) The mean distance the depôts are situated in reference to each section into which the town may be divided for conservancy purposes.

Portions of the town lying further away from the depôts will require a staff larger in proportion to the population as compared with districts nearer the depôts; again scattered districts require a larger proportionate staff than crowded localities per head of population.

If horses or ponies are used, the time of transit after collection of rubbish will be more speedy than if bullocks are employed.

It may be roughly estimated that bullocks when working nine hours per diem, passing through streets, waiting for the collection of the rubbish and then proceeding to the depôts and depositing rubbish will not cover more than nine miles or, say, one mile per hour.

A pair of bullocks will work a cart weighing 8 cwt. and containing 32 cubic feet or 17 cwt. of rubbish. The quantity of rubbish collected daily from 1,000 people varies much according to the nature of their food and habits, but it may amount to about 1 ton daily. In Bombay it is said to be only half a ton.

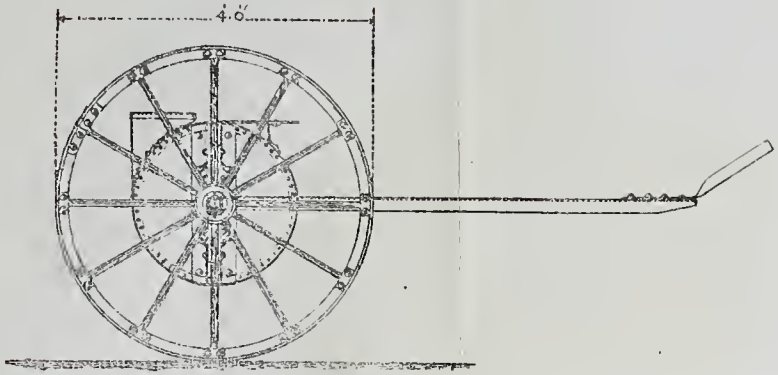
The number of carts may be roughly determined (having due regard to the considerations already referred to) on the following basis :—

Let P = Population in thousands.
Q = Tons of rubbish produced per thousand per diem.
X = Double the distance (mean) of any section of the town from the depôt.
M = The number of miles travelled per diem in collecting and depositing rubbish.
C = Capacity of cart in tons.

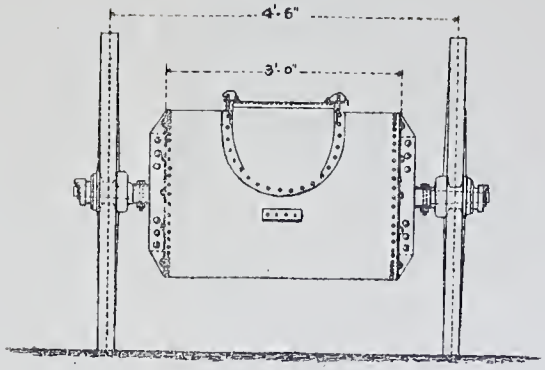
Then the number of carts required will be $\frac{P \times Q \times X}{M \times C}$.

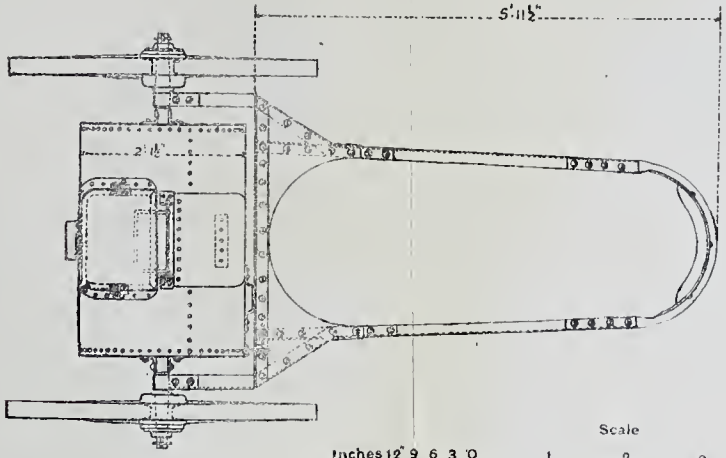
Take, for example, a section of a city with 10,000 people having its mean distance from the depôts as two miles and the capacity of its rubbish carts as three-quarter of a ton; suppose

SIDE ELEVATION



END ELEVATION





Scale

Inches 12 9 6 3 0 1 2 3 4 5 Feet

CYLINDRICAL NIGHT SOIL CART

CAPACITY { 60 GALS. / 10 C.F.T. WEIGHT 7 CWT

RICHARDSON AND CRUDDAS

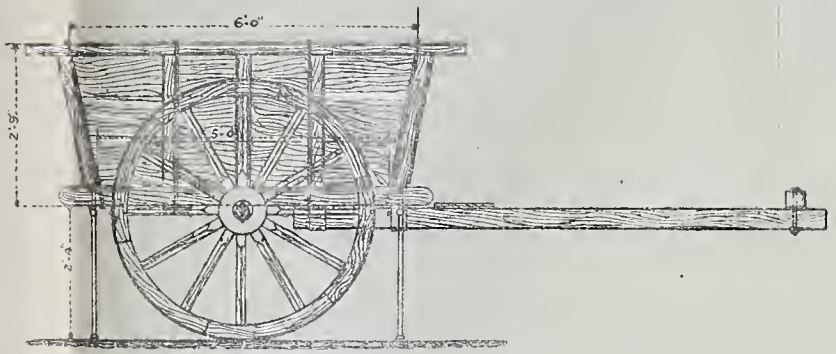
ENGINEERS

BOMBAY

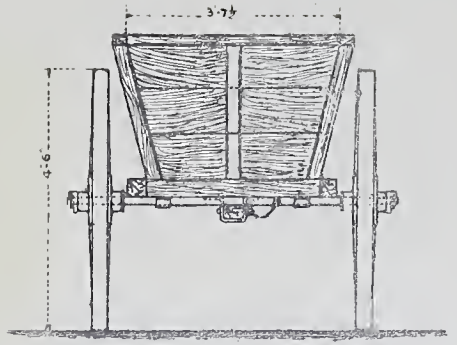
Cost Delivered in Bombay Rs. 185

Register No. 2281
Copies 1010

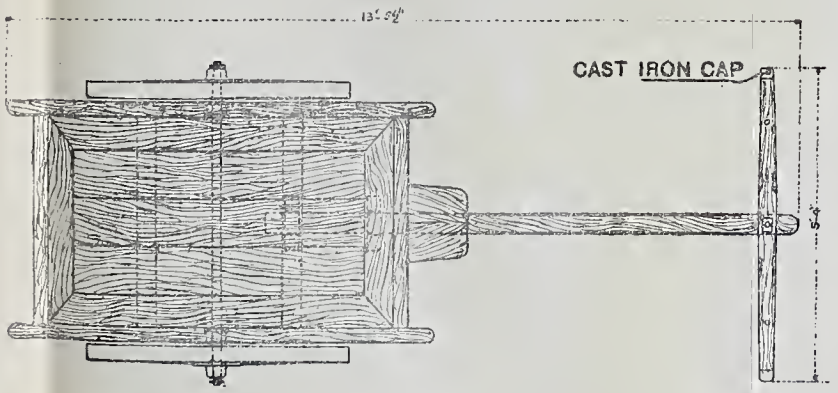
Photo-Zinco. Survey Office Madras.
1895



SIDE ELEVATION



END ELEVATION



RUBBISH CART

CAPACITY 35 C FEET

— Scale —

Inches 12 6 0 1 2 3 Feet

RICHARDSON & CRUDDAS

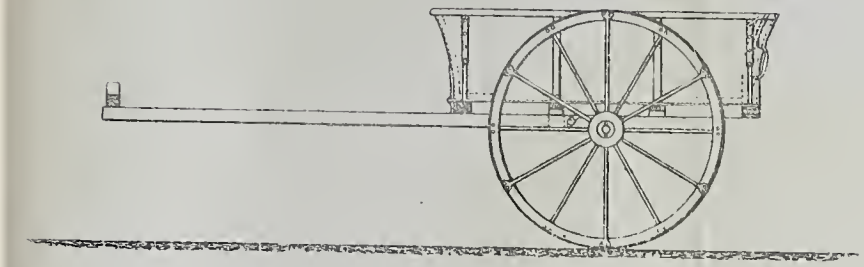
ENGINEERS

BOMBAY

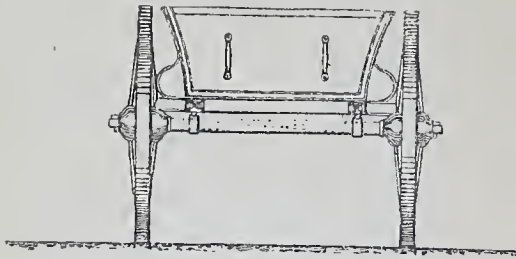
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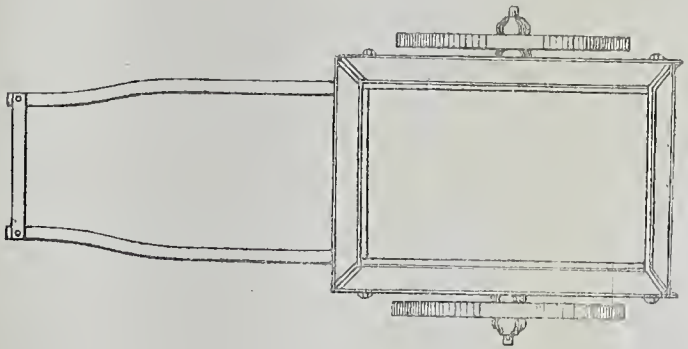
SIDE ELEVATION



END ELEVATION



PLAN



BURN AND CO'S

CONSERVANCY CART

CAPACITY 30 C. FEET
WEIGHT 6 CWTS
PRICE RS. 185

Scale.

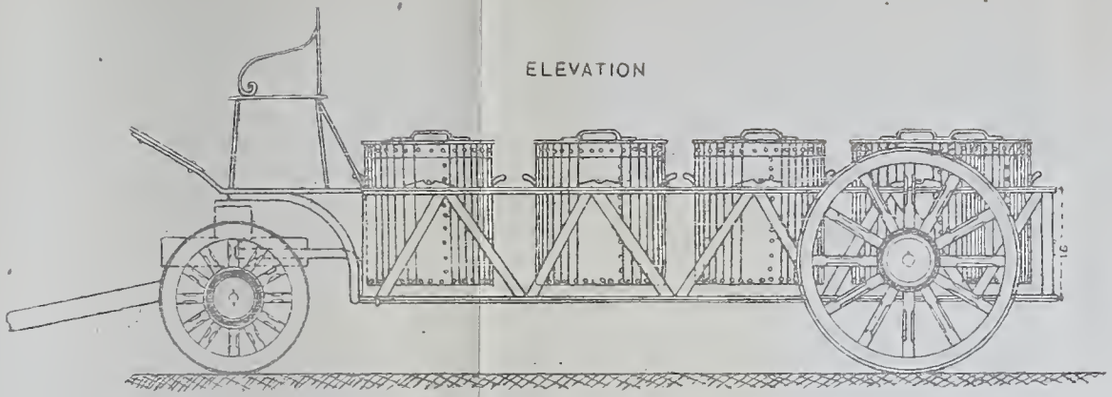


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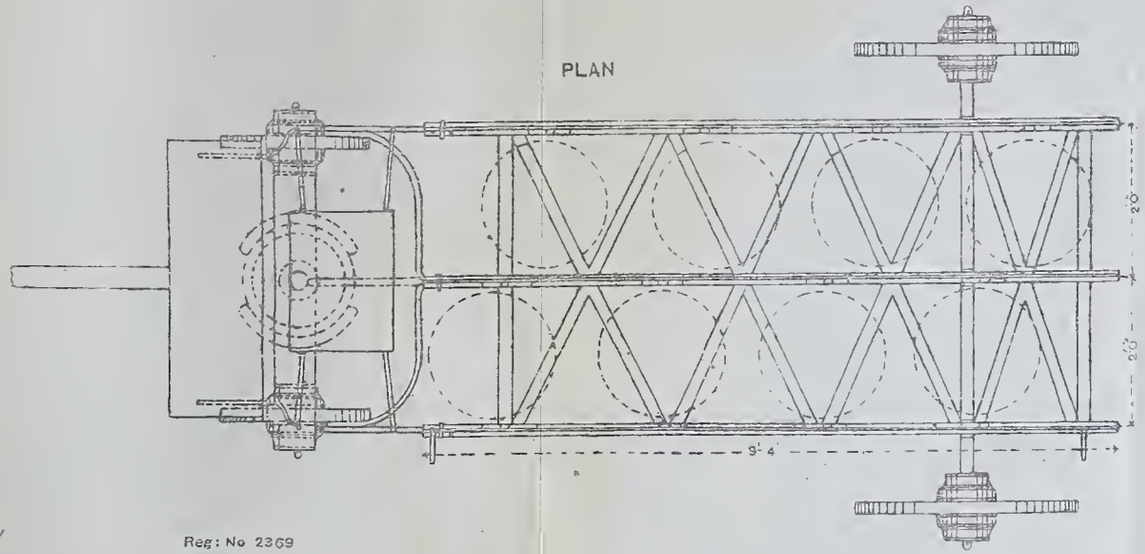
Photo-Zinco, Survey Office, Madras
1895

TROLLY AND NIGHT SOIL BUCKETS

ELEVATION



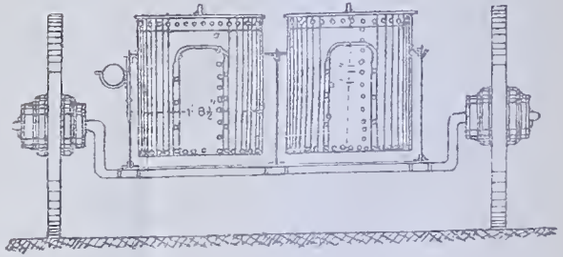
PLAN



Scale

1 0 1 2 3 4 5 Feet

END ELEVATION



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1896

that each bullock can travel nine miles daily and that the production of rubbish per 1,000 persons is a ton; then

$$\text{the number of carts required} = \frac{P \times Q \times X}{C \times M} = \frac{10 \times 1 \times 4}{\cdot 75 \times 9} = \frac{40}{6 \cdot 75} = 6 \text{ carts.}$$

The number of carts, &c., required for the collection of excreta can as easily be deduced. Experience in other adjacent towns is, however, a great guide, though it will be found that unaccountable differences exist in the amount of the staff which is very often the result of gradual growth and not an amount fixed with regard to any scientific principles and very often with little reference to the amount of rubbish which ought to be removed.

The next important matter is the class of plant which ought to be employed, that is to say, whether the carts ought to be wood or iron, and what their capacity ought to be, the most economical being of course those in which the weight of the cart itself bears the least proportion to the amount it carries. There are the further considerations as to whether the carts are to be drawn by horses, ponies, bullocks or men and the class of plant suitable for each.

It may be stated that for dry rubbish, open carts may be used, but that for all liquid sewage and solid or liquid excreta covered carts are indispensable.

The plates accompanying show various designs adopted in India with their weights and capacity and weight of material carried, and the cost of each cart as far as it has been possible to ascertain it.

Lighter carts and carts with brakes are required at hill stations where a somewhat different construction is required to that on the plains.

Tramways.

Necessity for tramways.—The difficulty of finding land close to a town for the deposit of rubbish and the objections against such deposit in too close proximity to a town have led many municipalities to consider the necessity for a cheaper means of transport to lands where rubbish can be disposed of unobjectionably.

Savings effected by tramways.—Tramways may traverse the main streets of a town but it is evident that they cannot be laid so as to allow of the direct reception into trucks from all parts and streets of a town. A double handling of

the rubbish and refuse is therefore a necessity; it is evident that unless this expense is counterbalanced by some saving in labour or time, it would not be expedient to adopt the tramway system for the removal of rubbish. The savings, which can be effected when a tramway is made available, are due to a less number of carts and animals being necessary, because of the easier traction, the greater load which can be carried, and the greater speed of transport. It is a matter for determination with regard to the special circumstances of each town when it ceases to be the most economical method of transport to convey the quantity collected by separate carts direct to a depôt; the point at which it is more economical to adopt the tramway system of transport depends chiefly on the proximity of the depôt and the distance which has to be travelled in the town area.

The saving, which can be effected by the substitution of a tramway for the distance traversed between the town and the depôt, is the difference between the cost of working the tramway (including interest on first cost, &c.) and the saving by the less number of miles requiring to be traversed by the carts and bullocks or ponies or whatever the draught power may be, a less number of carts and bullocks being required for the work owing to the omission of the distance the tramway traverses. A statement following shows the saving by substituting a tramway between a town and a depôt, the distance being 2 miles and the population 140,000.

Details of existing tramways.—A municipality having to decide questions such as the advisability of adopting a system of tramways for the removal of rubbish naturally looks to the experience of other towns. Many towns in India have adopted the system either for the conveyance of rubbish or excreta, or both. The following towns are among those which have done so:—

——	Length.	Gauge.	Weight of rail used.
	MILES.	FEET.	
Calcutta municipality	10	2	18 lb. per yard.
Ahmedabad do.	5½	2	14 lb. do.
Amritsar do.	5	2	14 lb. do.
Karachi do.	1½	2½	18 lb. do.
Bassein do.	3	2	10 lb. do.
Delhi do.	3½	2	14 lb. do.

Amritsar tramways.—The following information is extracted from a report by Mr. Nicholl, Secretary of the Municipality, on the working of the Amritsar tramway and affords valuable information as to the cost of, and the saving effected by, the introduction of such a work :—

"The matorial for the tramway arrived in Amritsar in October 1882, and by the 14th December tho 5 miles of line were laid. Of these only 2 miles were opened for conservancy work. The remaining 3 miles with a proportion of the rolling-stock were utilized in conveying earth to fill up the city ditch.

"The Municipality of Amritsar purchased 5 miles of straight line, with the necessary curves, crossings, 32 double-tipping wagons, two ballast wagons, one covered wagon and two passenger cars, with necessary tools and extras. The total cost delivered in Amritsar was Rs. 46,466.*

"The line is 2 feet gauge. The rails are steel, 14 lb. to the yard, supported on corrugated steel sleepers. By a simple system of clutch bolts, the gauge is maintained in whatever position the line is laid. The rails being made in 15 feet lengths, can be carried from place to place, relaid, and linked in by ordinary coolies, no skilled labour being necessary.

"The wagons are supported by four strong gudgeons upon wrought iron standards, and so balanced that they may be tipped right or left. The frame work is of channel iron carried on steel axles and spiral springs. The axles are fitted with grease boxes, the whole being carried on four chilled wheels, 14 inches diameter. The capacity of the body is 20 cubic feet and when full of earth can be propelled by one man.

"To demonstrate what the tramway is capable of doing and the saving of money effected by using it, two statements (A and B) are annexed.

"From statement A, it will be seen (column 2) the amount paid monthly for the removal of the sweepings of the city when donkeys only were employed; columns 3 and 4 show the present cost, and column 6 the saving effected.

"For some months tho conservancy wagons were employed in conveying earth to tho city ditch on the return trips. The value of the work done is shown in column 7.

"Statement B shows that during tho ten months, or from December 1882 till October 1883, 1,514,460 cubic feet of

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* This would cost now about Rs. 65,000.

earth were carried to the ditch from distances ranging from 500 feet to 2 miles and cost a trifle over Rs. 5,000. Now to have carried this quantity by the ordinary means, *i.e.*, donkeys and country carts, the cost would, at the very lowest estimate of Rs. 8 per 1,000 cubic feet, have amounted to Rs. 12,115 ; therefore the savings effected amount to Rs. 12,958, *i.e.*, on conservancy line Rs. 5,849.

"City ditch lines 7,109 or Rs. 1,295 per mensem.

"Deduct from this 6 per cent. interest on capital outlay and 6 per cent. for wear and tear = Rs. 4,650 ; there is still a clear profit of over Rs. 8,000 ; so that in six years the original outlay is repaid.

"There are other advantages which cannot be estimated in money ; they are (1) rapid removal of the filth from the city ; (2) no deposits are left on the line or road, as is the case when donkeys are employed ; their line of route could be distinctly traced and felt too by droppings from the bags or panniers ; (3) another and very important advantage is that you have always at hand a ready means of getting rid of earth or other matter from places where carts could not be employed. During the year the sludge from two tanks (the Durgiana and Koulsur) was removed in a very short space of time during the hottest part of the year, and the earth excavated from two tanks on the cattle-fair site was utilized in filling up hollows, thereby reclaiming valuable land. The advantages do not appear in figures, but they deserve mention.

"Statement C contains information that may be useful to anybody desirous of introducing the system on a small scale as an experiment. The Sanitary Commissioner with the Government of India, the Surgeon-General of the Punjab, the Sanitary Commissioner of the Punjab, the Commissioner of the Amritsar Division, and in fact all who have seen the system at work have expressed approval of it.

"On the conservancy line, horses are used ; one horse draws five wagons and does the work of 25 donkeys ; on the city ditch lines the wagons are propelled by coolies."

A.

Comparative Statement showing Cost of Donkey Establishment before introduction of Tramway and after.

1	2	3	4	5	6	7	8	9			10
Month and Year.	Cost of Donkey establishment under old system.	Cost of Donkey establishment since tramway was introduced.	Cost of maintenance of tramway horses and establishment.	Total of columns 3 and 4.	Savings as compared with figures in column 2.	Add to savings value of earth carried by conservancy tramway on return journeys.	Total savings due to the introduction of tramway.	Detail of tramway carrying agency.			Remarks.
								No. of horses.	No. of wagons.	Total number of wagon loads of manure delivered at depôts.	
1882.		1883.	1883.			1883.					
	Rs.	Rs.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.	Rs. A. P.				
January ...	1,906	1,376	219 0 0	1,595 0 0	311 0 0	...	311 0 0	12	24	1,653	
February ...	1,850	1,266	310 4 3	1,576 4 3	273 11 9	...	273 11 9	12	24	2,111	A wagon holds 10 donkey loads, and a donkey load is = 1½ c.ft.
March ...	1,877	1,117	216 5 6	1,333 5 6	543 10 6	...	543 10 6	12	24	2,141	
April ...	1,757	1,060	360 8 0	1,420 8 0	336 8 0	...	336 8 0	11	24	1,749	
May ...	1,627	807	315 8 9	1,122 8 9	504 7 3	170 0 0	674 7 3	11	25	1,472	
June ...	1,573	659	261 13 6	920 13 6	652 2 6	585 0 0	1,237 2 6	11	24	1,409	
July ...	1,585	685	287 10 9	972 10 9	612 5 3	242 0 0	854 5 3	11	25	2,409	
August ...	1,669	845	274 1 9	1,119 1 9	549 14 3	194 0 0	743 14 3	12	30	2,650	
September ...	1,555	779	248 13 6	1,027 13 6	527 2 6	...	527 2 6	12	30	2,575	
October ...	1,556	952	256 7 9	1,208 7 9	347 8 3	...	347 8 3	12	35	3,378	
Total ...	...	...	...	...	4,658 6 3	1,191 0 0	5,849 6 3	...	...	...	

B.

Statement showing the quantity of Earthwork done by the Tramway from December 1882 *till end of October* 1883.

Number.	Name of section.	Length of lead average.	Number of wagons employed.	Rate per 1,000 cubic feet.	Quantity delivered.	Cost of delivery, &c.	Remarks.
				RS. A.		RS. A. P.	
1	Hakeemanwala ...	2,000 ft.	8	2 12	89 8,940	2,443 4 1	
2	Hathee	500 ft.	9	2 8	376 ,520	921 8 11	
3	Kot Syud Mahmud...	2 miles.	20	4 0	201, 420	799 8 4	
4	Dingarh	1,500 ft.	10	3 0	37,580	112 11 6	Durgiana, Koulsur, digging by gangs, &c.
5	Miscellaneous ...	...	5	...	...	729 13 0	
	Total ...	...	...	...	1,514,460	5,006 13 10	

C.

Statement of cost of one mile of Portable Railway and twenty wagons delivered at Amritsar, Rails 2 *feet gauge,* 14 *lbs. per yard.*

Name of article.	Number.	Cost in England.	Cost in India with exchange at 1-7 $\frac{2}{16}$ added.	Freight and railway charges.	Remarks.
		£ s. d.	RS. A. P.	RS. A. P.	
Straight line	1 mile.	424 0 0	...	...	Supplied by John Fowler and Co., Steam Plough Wks., Leeds.
Curves, right and left ...	50 yards.	14 11 8	...	...	
Crossings, right and left, 24 feet radius.	4	21 8 0	...	...	
Crossings, two-way, 24 feet radius.	2	8 5 0	...	...	
Crossings, level, with planking.	30 yards.	19 17 6	...	...	
Double-tipping wagons, complete, C. pattern.	20	216 0 0	...	...	
Spares and tools	...	11 15 0	...	...	
Total ...	...	715 17 2	8,983 5 1	1,800 0 0	
Grand Total, say ...	...	...	...	10,783 0 0	

Cost of tramways.—The following comparative statement gives pretty full information in regard to the original cost and working charges of some of the lines previously mentioned :—

Particulars.	Karachi municipality.	Bassein municipality.	Ahmedabad municipality.	Delhi municipality.
1. Population of town ...	104,250	28,000	143,664	193,583.
2. Population served by line.	62,000	10,000	143,664	120,511.
3. Length of line ...	1½ miles	3 miles	5½ miles	3½ miles.
4. Gauge of line ...	2 feet 6 inches ...	2 feet	2 feet	2 feet.
5. Particulars of weight of rails and as to sleepers, ballasting, &c.	Weight of rail 18 lbs. per yard; babul wood sleepers 4′×8″×6″; ballast 6″ thick.	Weight of rail 10 lbs. per yard; steel sleepers ballasting level with existing roads.	Weight of rails 14 lbs. per foot; wrought iron sleepers; no ballast.	Fowler's 14 lbs. rails and patent clutch bolt sleepers; no ballast.
6. Particulars of any bridges on the line.	Small culverts of common rubble masonry, line carried on wooden beams and roadway planked.	Constructed over existing bridges.	Small culverts; no bridges.	*Nil.*
7. Details of rolling-stock—				
(1) Number and class of engines.	(1) No engines ...	(1) No engines	(1) No engines, 9 pairs of bullocks and 2 horses.	(1) No engines, 20 horses and 10 bullocks.
(2) Number and dimensions and capacity of trucks.	(2) 40 trucks made of wrought iron Fowler and Company's side-tipping pattern; body 4′ × 5′—6″; capacity 35 c.ft.	(2) Vans and wagons as per John Fowler's patent; capacity of trucks (average), 30 c.ft.	(2) 60 tipping wagons of 20 c.ft. each and 20 iron barrels of 100 gallons each.	(2) 50 tipping wagons with lids of 30 c.ft. each.

Particulars.	Karachi municipality.	Bassein municipality.	Ahmedabad municipality.	Delhi municipality.
8. Amount of rubbish removed daily and number of trips made.	20 trucks × 4 trips ×35 c.ft. = 2,800 c.ft. removed daily.	300 c.ft., 10 trips daily.	Night-soil only removed, rubbish removed by carts drawn by bullocks ; 33 carts, four to five trips daily.	3,000 c.ft., in two trips.
9. Particulars of the mode of deposit and after treatment of the sweepings, whether used to fill up swamps and if cultivation is effected thereafter.	Road sweepings burned; filth and dead animals buried in pits.	Sweepings are made use of for agricultural purposes ; not used for filling in swamps.	Sweepings deposited in two depôts and sold for cultivation.	Sweepings sold almost fresh to cultivators.
10. Cost—				
(1) of carriage of rubbish to line.	(1) Rs. 1-6-10 per 100 c.ft.	Line constructed on existing road and worked by conservancy establishment and maintained by permanent gangs who keep the roads in repair.	(1) Cost of carriage of night-soil to loading stations Rs. 27,725 per year ; of sweepings to the depôts by bullock carts Rs. 10,500 annually.	
(2) of working line daily.	(2) Rs. 13	.....	(2) Rs. 5,600 annually.	

(3) of carriage per ton and per head of population.	(3) Rs. 2–6–0 per ton.	.....	(3) 6 annas per ton.	Line just started (1891); no statistics available.
(4) of deposit.	(4) 3 annas per ton ...	.....	(4) Rs. 2,600.	
(5) of amount of any after expenditure.	(5) *Nil*	.....	(5) Repairs to trucks Rs. 600.	
(6) of annual repairs to line.	(6) Rs. 300 annually ...	.....	(6) Repairs to line Rs. 600.	
11. Cost of engines, trucks, brake vans, &c.	Trucks cost Rs. 250 each.	Manual labour; no locomotives are employed.	No engines; cost of trucks Rs. 160 each and brake-vans Rs. 179 each.	No engines; 30 c.ft. tip wagons cost Rs. 250 each.
12. Cost of rails, sleepers, ballast, &c., and construction of line.	Line laid with old rails and old sleepers; original cost cannot be given.	Cost of rails, sleepers, &c., per mile Rs. 4,100.	Cost of rails and sleepers Rs. 4,650 per mile; no expenditure except line repairs, as only moorum or brick bats are used; construction of line Rs. 500 per mile.	Cost of rails and sleepers Rs. 5,000 per mile; no ballast; construction of line Rs. 300 per mile.

The following points require notice in regard to the above statement. The Karachi line was laid with old rails and sleepers; this plan is sometimes cheaper than the purchase of even very much lighter material. At Bassein the sweepings are used for agricultural purposes and the line kept in repair by the ordinary road staff and conservancy establishment. The night-soil is removed in special air-tight vans during the night; it is deposited in trenches 10 feet wide and covered with fresh earth. The place of deposit is 1 mile outside the town. The Ahmedabad tramway is used for conveying night-soil and sullage water to a distance of 3 miles from the city; no sweepings are carried over the line (1891).

It will be noticed that no engine power is used on these tramways; this, where the distance to the depôt is comparatively short, is unnecessary, and no new bridges, or strengthening of old bridges is required as might be the case if engines were used.

Estimation of cost of, and savings due to use of, tramways.—The cost of any tramway will depend chiefly (1) on the weight and cost of the rails, (2) the cost of ballasting, (3) whether the line can be laid along existing roads or not, (4) the cost of the plant. The cost of working per mile will depend (1) on the power used, (2) the efficient or non-efficient manner in which the line has been laid and (3) the character of the material ballast of which it has been constructed.

The following estimate gives an idea of the cost of 2 miles of average light tramway and plant for the conveyance of the rubbish for a population of 140,000 people. The tramway is supposed to be laid along a road side and no banking or cutting required:—

Estimate for 2 *miles of light Tramway and Plant for the conveyance of Rubbish for a Population of* 140,000.

	£
Two miles of rails, 24″ gauge, 14 lbs. per yard, with corrugated sheet, sleepers and all fastenings complete, at £360 per mile	720
Curves, right and left, 100 yards	30
Right and left hand crossings, 8 No.	49
Two-way crossings, 4 No.	18
Level crossing (wood planking), 30 yards ..	20
One quarter mile of light 10 lbs. rails at trenching ground and crossings	70
Tools, &c.	33
Total ..	940

	£
Double-tipping wagons complete, C. pattern, No. 75 *	900
Total ..	1,840

	Rs.
£1,840 at exchange 1*s.* 1*d.* .. .. =	34,000
Laying line, 2 miles .. .. .. =	1,200
Cost of depôt .. .. =	1,000
Carriage, contingencies, &c. .. .. =	1,800
Total ..	38,000
Add to this cost of 15 † horses at Rs. 500 ..	7,500
Total outlay ..	45,500

Annual maintenance charges of the tramway and horses—

	Rs.
Interest on first outlay at 4 per cent. on Rs. 45,500	1,820
Maintenance and repairs to wagons, and tramway at 6 per cent. on cost of tramway and wagons on Rs. 38,000	2,280
Maintenance charge of 15 horses at Rs. 360 ‡ a horse	5,400
Total annual charges ..	9,500

No charge is made for transfer from carts to wagons, as that cost is now incurred at the depôts. There will be a small expenditure at the depôts for emptying the tipping wagons.

The number of miles which would be travelled (full and empty trains) would be $365 \times 2 \times 2 \times 4 = 5{,}840$ per annum.

The number of tons $140 \times 365 = 51{,}100$ per annum.
Each ton is carried — 2 miles.

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* Each wagon holds 20 cubic feet.
The rubbish from 140,000 people per diem weighs 140 tons.
1 cwt. of rubbish $= \frac{35}{17}$ cubic feet.
140 tons of rubbish $= \frac{35}{17} \times 140 \times 20 = 5{,}765$ cubic feet, or $\frac{57650}{200} = 288$ wagons.
But as four trips can be made in a day, the number of wagons required $= \frac{288}{4} = 72$, say 75 wagons.

† One horse can draw 100 cubic feet or a train of 5 wagons of 20 cubic feet each.
The number of horses required for 75 wagons $= \frac{75}{5} = 15$ horses.

	Rs.
‡ Each horse costs a month for maintenance including a driver	20
Monthly depreciation on first outlay on a horse	10
Monthly maintenance charge for each horse	30
Annual maintenance charge for each horse	360

Including return empty — 4 miles.
Or ton miles including return — 817,600 per annum.
Cost per ton mile $= \frac{9500 \times 16 \times 12}{817600} = 2{\cdot}2$ pies per ton mile, or
$= 1{\cdot}1$ pies per ton mile if return distance omitted.

Annual charges of removing rubbish to trenching ground by bullocks and carts by road—

	RS.
Interest on cost of carts, Rs. 5,500 * at 4 per cent.	220
Repairs to carts at 10 per cent. on Rs. 5,500.	550
Maintenance charge of 55 pairs of bullocks at Rs. 225 † each pair	12,375
Total annual charges ..	13,145

The cost for any other population can be found in a similar manner by reducing or increasing the number of horses and wagons in proportion to the population and increasing or reducing the cost of the line proportionately to the cost of the first item. A short tramway is therefore comparatively more expensive than a longer tramway, that is, per mile of line. The cost of the plant depends of course on the quantity of rubbish to be carried.

If road or other material can be brought back in the empty wagons, the cost of working for conservancy purposes can be much reduced.

WATERING ROADS.

The watering of roads is a sanitary measure of importance; while it adds to the comfort of the inhabitants, it has a considerable influence in preventing undue wear of the roads. It is also a protective measure as it prevents clouds of decaying refuse being distributed.

To show to what an extent this process is considered necessary in England, in London alone 1,500 men and 1,500 horses and carts are employed and 30,000 tons of water are

---

* To carry 140 tons of rubbish, the number of carts $= \frac{140 \times 20}{17} = 165$ carts.
Each cart can make three trips daily: the number of carts required will be $\frac{165}{3} = 55$. This number can, therefore, be saved and the cost will be at Rs. 100 = Rs. 5,500.

† The hire of a pair of bulls for a month = Rs. 18-12-0.
Therefore the hire of a pair of bulls for a year = Rs. 225.

spread on the streets every dry day, the cost being £200,000 annually for an average of 120 days.

There are several plans possible of adoption in India; the following are the most common :—

(1) Sprinkling water from mussucks by hand.

(2) Sprinkling by water carts.

(3) Damming up water in the gutters and throwing it on the road with shovels (useful on ghâut roads).

(4) By means of portable perforated pipes attached to the hydrants.

(5) By means of hose with roses at the ends.

The first two are the more ordinary methods; the latter two can be used only when there is a perfect water-supply system, and when the hydrants on the mains are placed at short distances apart.

It is always advantageous to obtain water from a source, which will deliver it above the level of the road as then carts and mussucks can be more conveniently filled. Where water cannot be put into the carts without lifting it, possibly the mussuck system is the best and this system is adopted even in Calcutta although the mussucks are filled from the hydrants.

The following are some points to be considered in arranging for street watering when there is a water-supply system :

(1) The number, position and class of hydrants.

(2) Size, form, design and capacity of the carts to be employed, the points to be aimed at being strength, lightness of draught, durability, great width of spread, evenness of distribution so as not to leave pools or dry patches, or to cause dust to rise behind the cart.

(3) The class of hose to be used, leather or canvass; canvass is probably the more suitable for India as leather, unless particularly well cared for, is liable to crack.

(4) The driver should be a man of some intelligence.

In road watering a check should be kept on the driver, and an indicator fixed on the cart, showing the amount of water used, is most advantageous in that respect.

The greater portion of the work of watering really consists in travelling backwards and forwards to fill; a very small proportion of the time is used in actual distribution. This shows the necessity for having hydrants comparatively near to one another, and the capacity of the cart should be fixed in reference to the distance the hydrants are apart; for instance, the capacity of the cart should be as nearly as

possible equal to the amount of water used between one hydrant to another. This is, however, not always possible. Again, the capacity of the cart is limited according to whether horse or manual labour is employed, and the decision on this point must be on a financial basis.

Some time ago an account was kept of carts working in London $10\frac{1}{2}$ hours per day exclusive of breakfast and dinner hours: out of that time it was found that—

	H.	M.
Filling occupied	1	20
Distribution only	0	50
Travelling	8	7

The number of hydrants was then increased and the following improvement was found:—

	H.	M.
Filling	2	0
Distribution	1	30
Travelling	6	30

The latest style of cart used in England is known as Bayley's van made of wrought iron measuring 8′ × 4′ 8″ × 2′ 0″ deep, holding 450 gallons; this is drawn by one horse.

When the draught used is bullocks or men, the carts are made much smaller, and the hydrants should therefore be comparatively closer together than when carts of larger capacity are employed.

In the accompanying plate are shown the carts adopted by the writer when Engineer of the City of Madras. They consist of an iron barrel concentric with the wheels and carried on the axle which passes through the barrel.

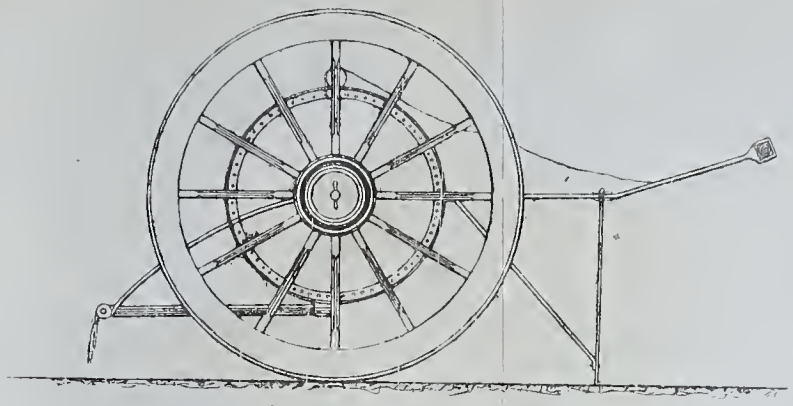
The carts are made of various sizes adapted to the distance the hydrants are placed apart.

Description of cart.	Barrel.		Wheels dia.	Weight.		Contents.	Cost.
				Empty	Full.		
	DIAM.	LGTH.		CWT.	CWT.	C. FT.	RS.
Suitable for 2 men.	2′ 9″	2′ 4″	5′ 0″	6·5	14	14	125
Do. 3 men.	3′ 6″	2′ 6″	5′ 0″	7·5	21	24	140
Do. 1 pair of bullocks ...	3′10″	2′10″	5′ 0″	9·0	27	32	175

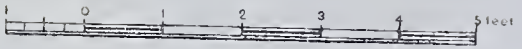
To water a road once sufficient to keep down the dust requires 15 cubic feet of water for each 900 square yards or

WATER CART

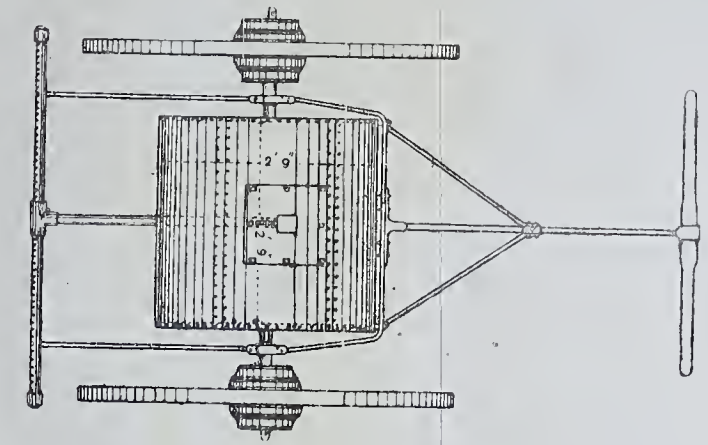
ELEVATION



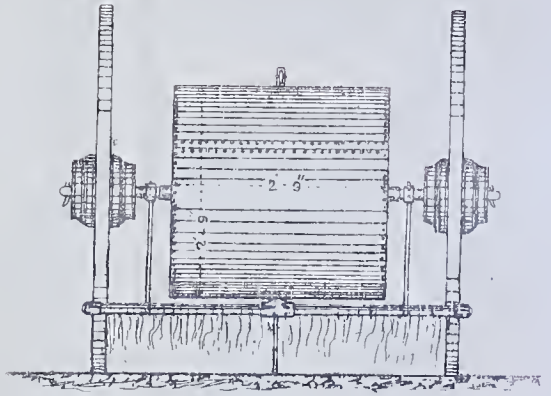
Scale



PLAN



ELEVATION



Register No. 2370
Copies 1010

Photo-Zinco Survey Office Madras
1896

1 cubic feet for each 60 square yards or for each 9 yards of road 20 feet wide ; the cost (in Madras) is 4½ annas per 100 square foot per annum (watered twice daily). On wet days no watering is of course done.

The points in designing a water cart which require attention are (1) to ensure sufficient pressure ; this may be done by keeping the tank or barrel fairly high and joining the spreading pipe by an easily curved connection ; (2) the spreader or distributing pipe ought to be placed as low as possible, and to ensure a regular trajectory, the holes in this pipe should be placed on a curve (and not drilled in a straight line) rising from the point where the water enters from the tank.

Watering streets with sea water should be adopted when possible ; this gives freshness to the air, dispels iodine and causes the surface of the street to retain its humidity for a longer period than when fresh water is used as it impregnates the soil with hygrometric matter. Common salt added to fresh water or chloride of calcium is also beneficial ; an experiment was made at Rouen in France, where for a mile of road 16 feet wide, 5,630 gallons were necessary daily and the same result was obtained with 1,480 gallons of chloride solution costing ½*d.* per gallon, the humentation remaining good for five or six days.

Watering roads with largely diluted disinfectants such as 'Sanitas' is frequently of great benefit and should occasionally be done especially in the narrow and more crowded streets of a town.

PART II.

SANITATION IN REGARD TO SPECIAL BUILDINGS, LOCALITIES, OCCUPATIONS AND TRADES.

BUILDINGS GENERALLY.

The sanitation of buildings is a no less important matter than the cleansing of towns as a whole, and when sanitation of buildings is spoken of, it is implied that not only must certain sanitary rules be enforced as regards all buildings, but that all buildings shall be originally constructed on sanitary principles.

The consideration of the various materials used in the construction of buildings, their water-supply and drainage form the subjects of other chapters in this work, but when discussing the sanitary requirements of buildings, it is advisable to refer to certain characteristics of construction, water-supply and drainage which each class of buildings should possess.

DWELLING HOUSES.

In a previous chapter it has been pointed out that pure air and pure water are two indispensables to ensure good health; these often are present and still houses are unhealthy; good drainage and an absence of dirt and damp are also important factors.

The word dirt or 'matter in the wrong place' includes dust, refuse, rags, &c., of every kind. There may be fœtid odours in houses arising from defective drains or latrines and deficient ventilation; but there is often to be found an odour distinct from these which is caused by the exhalation from animal bodies, human, or otherwise dirty clothes and general dust. All such odours, of course, point to an increase of carbonic acid in the air and to what extent that may be increased without harm has been laid down in chapter I.

There is one item that enters very largely into house sanitation and that is the construction and maintenance of the roads, for badly-constructed roads are sure to be dirty roads and will cause dirty houses. This, however, is a matter more for the public in general than for a householder in particular.

A sanitary house should have a sufficient supply of good water; it should have good drainage, and it should be constructed so that no water, clean or otherwise, should be able to permeate through the floors or in its immediate vicinity unless sub-soil drainage is provided. This in India is seldom possible, and care should, therefore, be taken to see that all refuse waters are disposed of so as to readily find their way to drains; latrines should be apart from the house, but not far enough to meditate against their necessary use. Each house ought to be arranged so that each room has some of its windows opening direct to the open air and that light and ventilation are not borrowed from another room. Houses should be raised at least 2 feet above the ground level, and this is required in the case of all new houses under the provisions of the Municipal Acts.

Classification of houses.—Houses in India are constructed of—

1. Leaf walls and roof.
2. Bamboo mat walls and thatched roof.
3. Mud walls and thatched or tiled roof.
4. Brick { in mud / or / in mortar } walls and { thatched roof. / tiled roof. / terraced roof.

The first of these classes are usually to be found in parcherries, their floor is usually level with the ground, and while the ventilation is perfect enough, their construction is such that cold and fever are induced; perhaps much of the phthisis in India is due to this class of building.

The second class of building is much superior and may be recommended for temporary buildings such as contagious disease and other hospital sheds, because the matting is easily cleaned by white-washing or tarring, or it may be taken away and replaced.

Mud wall huts are extremely common in all parts of the country, and where the walls are properly protected by the roof, a very fair building may result. The walls, however, are apt to absorb moisture and several fatal accidents have occurred through water having found its way into the walls.

Rising again in the scale are those houses which have their walls of brick, sun-dried or burnt, laid in mud which may have thatched or tiled roofs. The highest class of building is that built of burnt brick or stone laid in mortar or cement and covered with a tiled or terraced roof.

Municipal powers.—The powers given by the Municipal Acts to local boards in respect to buildings refer chiefly to ventilation and drainage, but bye-laws can be made and these should lay down stringent conditions as to the thickness of walls (having regard to their height and the area to be roofed), as to the size of floor and roof timbers, minimum slope of roof, &c.

Prevention of damp.—All buildings should have floors of such construction as will exclude damp arising from the ground; in the lower class of houses, puddled clay would be suitable if rammed until quite hard and dry; an improvement over this is a thin layer of cement concrete; better class houses are floored with a thick layer of concrete or with concrete and a layer of bricks or tiles superimposed.*

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* *See* Chapter on Buildings.

The walls of houses should be, as far as possible, damp proof ; the damp may enter in two ways, up the wall from the ground or through the wall from the outer air : the former is prevented by what is called a damp-proof course.* Plastering the walls inside and out with mud, chunam or cement tends in increasing degrees to keep out damp from the outer air.

In all cases walls ought to be perfectly smooth and made with the least absorbent materials it is possible to procure.

Plastering walls or floors with cow-dung is to be condemned, because it renders them damp and affords material for the propagation of micro-organisms and pollutes the air. White-washing walls periodically with fresh burnt lime is an excellent measure.

SLAUGHTER-HOUSES.

These buildings, however well conducted, are generally a nuisance to a greater or lesser extent. They should be placed, therefore, at some distance from the inhabited portion of the town area and on that side of the town opposite to that from which the prevailing winds blow. They ought not to be near any stream, and they ought to have large open spaces within easy distance of them, where offal can be burnt or buried without nuisance, or otherwise disposed of at some distance from the slaughter-house itself.

Requisites.—The first requisite as regards the conservancy arrangements in a slaughter-house is a good water-supply, the second good drainage. Thorough cleansing is necessary both after the morning and evening killing is over. The floors ought to be thoroughly sluiced with water and effectually cleaned by the use of squeegees such as are used for paved railway platforms, &c. All slaughter-houses ought to be lime-washed at least once in every three months.

Disposal of blood.—Putrefied blood gives forth a most offensive smell, and it is, therefore, necessary to dispose of this immediately after collection; it should not be allowed to flow into any of the town drains, but into cesspools or drains in connection with the slaughter-house alone. The blood should be buried or converted into manure by a process of evaporation, when it becomes very valuable manure.

Supervision.—There is great advantage in slaughter-houses being the property of, and under the control of, the

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* *See* Chapter on Buildings.

sanitary authority, as that authority can then by its superintendent keep a proper watch over the food-supply of the town. The sale of the right of collection of fees is sometimes advisable; it allows the superintendent and other officials of a slaughter-house to attend to their legitimate duties, viz., the regulations and control of the house and the proper examination of all animals brought to be slaughtered. A careful account of the number of animals slaughtered should be kept with their weight if possible. Such an account affords a basis for the determination of prosperity or otherwise of a town as evidenced by the rate of the demand for meat. A small supply may, however, be due to other causes than a small demand, and a reference to market prices will show whether this be the case or not.

The mode of slaughtering in India is open to many objections, but it is, to a great extent, mixed up with the religious prejudices and scruples of the Mahomedan butchers and therefore somewhat difficult to deal with. Unnecessary cruelty in any form should be most summarily dealt with.

MARKETS.

Good drainage and an ample water-supply are as requisite in a market as in a slaughter-house. The floors should be regularly swept and cleansed, the stalls where meat, vegetables, &c., are sold should be washed and scrubbed daily. The walls of the market should be lime-washed frequently, not less than once in three months. Latrines and washing places should be provided in sufficient numbers and properly cleansed.

Advantages of a market.—By concentration at one place under one roof, the cost of transport and distribution are made easier to the trader, and the purchaser is able to make a better and cheaper selection of the commodities. To municipal authorities, a market offers facilities for sanitary examination of food, inspection of weights and measures, &c. Market-tolls usually form an important source of municipal revenues, if the markets are, what may be called 'public markets,' viz., those built and maintained at public expense.

All markets ought to be public markets.—In India it is well for the markets as far as possible to be public ones; it is otherwise a matter of much difficulty (such at any rate is the writer's experience) to enforce necessary sanitary regulations.

Restrictions on sale of fish and meat outside markets.—The sale of fish and meat should, as far as possible, be restricted to markets; in Madras no butcher's shop is licensed within a mile of any market.

Opposition to new markets to be expected.—Opposition to any new market, unless it is a market to be opened in place of an existing public one is generally manifested, but opposition of this kind may generally be conciliated by the first offer of the stalls in the markets about to be constructed.

Market sites.—A site for a market should be free and open and as near as possible to a place where the main streets of the town converge; it should be capable of easy drainage. Contiguity to railway stations, important bridges, &c., are also points to be considered in fixing a site.

Principles by which the working of a public market ought to be regulated.—The principle of a public market demands free trade and competition, and care must be taken that the normal tendency of traders to combine against the interest of the public is not assisted nor in any way encouraged by the market regulations. It is generally disadvantageous to farm out the tolls to one lessee, to allow the stalls to be occupied by cliques or trades unions to the exclusion of the independent trader, or to make conditions too onerous for traders of small capital. So long as the tolls demanded, considering the conveniences afforded, do not exceed what a free competition outside the market would produce, the revenue may be considered a fair rent; if too stringent regulations are imposed on traders outside the market or anything in the form of a monopoly granted to those inside, then the higher revenue which would be so obtained becomes a tax on the commodities and in fact a sort of octroi duty.

Where private slaughter-houses exist, additional food inspection necessary in markets.—Where the slaughter-houses in a town are not all public slaughter-houses under municipal supervision, it is doubly the duty of the market officials in the public markets to be constantly on the watch to pr vent the sale of diseased meat, putrid fish and other unwholesome food, and where there are public as well as private markets, much supervision by the sanitary officials is desirable; inspection of such markets should never be made twice at the same hour of the day; inspection made constantly, say, before 9 A.M., may as well never be made at all.

LATRINES.

Latrines are arranged on so many different plans that a conservancy system applicable to one class does not admit of its application to another. Certain general rules may, however, be laid down for guidance.

Cleansing.—Where latrines are practically water closets, the attendant should, if the latrine is on the trough system, discharge the contents frequently and change the water. When latrines are on the pail system, the contents of the pails after each occasion of use should be filled in with an inch or two of ashes, charcoal or earth and the pails removed when moderately full. When on the open floor system, removal of the excreta should be effected at once after vacation of each seat. In such latrines the floors ought to be sluiced once or twice daily with some disinfecting fluid such as mixture of phenyle and water (1 to 100). The urine tubs before use should also be partly filled with a similar fluid.

Where the walls or screens of latrines are of masonry, they should be tarred once a month to at least half the height of the walls, say, 4 feet, and all walls of latrines whether of stone, brick, iron or wood ought to be frequently washed with a strong disinfectant.

The removal of all excrement and urine should be in air-tight vessels, and the place for the temporary deposit of such vessels should be screened from view.

Public latrines are all more or less a nuisance and their use by the public will, to a great extent, depend on their cleanliness or otherwise. There is little doubt, but that at present many persons are driven away to open spaces because of the state of the public latrines, and one can hardly blame them if latrines are not properly and promptly cleansed as occasion requires.

Temporary Latrines.—With reference to latrines of a temporary nature such as those at fairs and festivals, their site should be selected with due regard to the directions of the sub-soil flow, the situation of wells, water-courses, &c. Pits with foot-boards over them make excellent latrines and deposits should be promptly covered by the earth excavated from the pit. When the top of this earth in any pit reaches to within 2 feet of the ground, that pit ought to be closed and filled in level with the ground and a fresh pit brought into use and used in a similar manner; screens of bamboos

can be used to secure privacy and Horbury's latrines can also be adapted to the purpose.

DAIRIES.

This word is comprehensive enough to include all places where milch cattle are kept, though perhaps few of such places in this country deserve the name. Under the heading of food in the chapter on Hygiene, the necessities for a pure milk-supply have been pointed out, and it has also been shown how the condition of places, where milch cattle in India are housed, almost prevents a pure milk-supply being obtained.

Existing conditions.—Places for the keeping of milch cattle are required to be licensed by the Municipal Acts, but few of such places even after years of Municipal control are fit to be licensed. They are usually ill-paved, ill-ventilated and badly drained, and therefore a nuisance to the surrounding neighbourhood. The sheds are as often thatched and tiled and the floors are of an absorbent nature.

Requirements.—All such places should have impervious floors of brick or stone laid on concrete, the joints well filled with Portland cement, of good cement concrete or of brick on edge covered with asphalte. Of whatever the floor is made there should be no soakage through it. The drains ought to be open, looking to the nature of the material which will pass into them, and they should have stone edges which are not easily broken by the passage of cattle over them. The dung from such places ought to be removed daily. It is usually made into bratties, so perhaps this is a condition difficult to insist upon. Where the roofs are permanent and tiled, there ought to be ridge as well as eave ventilation. The insides of the walls ought to be lime-washed once a month and the floors occasionally sluiced with some disinfecting fluid. A common result arising from penning up cattle in ill-ventilated and filthy pens is the propagation of foot-and-mouth disease, rinderpest, anthrax, &c., diseases highly infectious and contagious. When such diseases occur, the whole of the upper surface of the floors of the sheds and the material of which the open yards are formed ought to be dug up and removed. All matting and thatching ought to be burnt and the sheds ought to be thoroughly washed with strong disinfectant and then lime-washed throughout before use.

English regulations.—The cleanliness of such places is a matter of the utmost importance to the public and the

danger of the present state of matters is very seldom realized. In England and other European countries very strict regulations prevail in regard to such places. At present the powers of regulation available in India are insufficient to enforce such regulations, which are as follows ; the first set of regulations has reference to the dairies themselves and to places where milk is sold, the second to the action required in case of anthrax (a common disease in India) breaking out :—

Dairies.

I. Persons following the trade of cowkeepers or dairymen shall provide to the satisfaction of the local authority, for a sufficient supply of pure, wholesome water as well as for effectual lighting, ventilation, cleansing and drainage of all dairies and cow sheds in their occupation, and shall cleanse and make clean every cow shed in the following manner :—

(1) By removing, at least twice in each day, all the dung, droppings, or other matter, and thereafter by the thorough scraping and sweeping of all parts of the cow shed with which the animals or their droppings have come in contact.

(2) By the application to the inside walls and roof of a coating of lime-wash containing in each gallon of lime-wash 4 ounces of chloride of lime, at least twice in the year, in April or May, and in October or November, and by thoroughly scraping, washing and scrubbing with clean hot water and carbolic soft soap all the stalls and exposed woodwork.

II. Persons following the trade of cowkeepers, dairymen or purveyors of milk shall cleanse and make clean every dairy, milk store, or milk shop in their occupation in the following manner :—

(1) By thoroughly washing and scrubbing daily, with clean hot water and soap, all counters, shelving, flooring, and exposed woodwork.

(2) By the application, at least twice in the year, in the months of May and November, to all parts of the inside walls and ceiling of a coating of lime-wash, containing in each gallon of lime-wash 4 ounces of chloride of lime ; and

(*a*) shall scald with boiling water or steam under pressure immediately after use, all barrels, butts, cans, and other vessels of whatever kind used to convey, store, or distribute milk for sale, including bungs, bung cloths, lids, &c., and thereafter drip them so as no water can be left therein ; but

(*b*) no boiler, tank, steam chest, or other receptacle used for scalding or washing the milk vessels shall be employed for washing or boiling bed or body clothes,

or for any other purpose likely to cause contamination of the milk, or

(*c*) milk vessels or utensils, washed, scalded, or kept in any apartment used for washing or boiling bed or body clothing, or

(*d*) foul matter of any description, or solid bed or body clothing conveyed into or through any apartment in which milk is kept or stored for sale; and

(*e*) no cart or other vehicle used in the distribution of milk shall be permitted to carry any article or thing which is of such a nature as to be likely to contaminate the milk.

III. Should cholera, small-pox, fever, measles, hooping cough, or any other infectious or contagious disease exist on the premises of any cowkeeper, dairyman or purveyor of milk, such cowkeeper, dairyman, or purveyor of milk shall forthwith report to the Sanitary Inspector the name or nature of the disease, so that the local authority may be enabled to see that the necessary precautions are being taken to prevent the spread of the disease.

IV. Every person following the trade of cowkeeper, dairyman or purveyor of milk, or being the occupier of a milk store or milk shop, shall, when required by the Sanitary Inspector or any member of the local authority or any person duly authorised by them, cleanse his or her cow shed, dairy, milk store, milk shop, or milk vessels in the manner hereby described.

V. Every cowkeeper, dairyman, or purveyor of milk failing to comply with the foregoing regulations, or any of them, shall be deemed guilty of an offence against 'The Contagious Diseases (Animals) Act, 1886,' and liable to a penalty not exceeding 5 pounds.

NOTE.—By the dairies, cow sheds, and milk shops, order of 1885:—

I. It shall not be lawful for any person following the trade of cowkeeper, dairyman or any purveyor of milk, or being the occupier of a milk store or milk shop,

(1) to carry on in the district of any local authority the trade of cowkeeper, dairyman, or purveyor of milk, unless he is registered as such;

(2) to begin to occupy any building as a dairy or cow shed without giving one month's notice in writing to the local authority of his intention to do so;

(3) to occupy, as a dairy or cow shed, any building so long as the lighting, ventilation, air-space, cleansing, drainage, and water-supply thereof are not such as are necessary or proper for the health and good condition of the cattle therein, for the cleanliness of milk vessels used therein for containing milk for sale, and for the protection of the milk therein against infection or contamination;

(4) to allow a person suffering from an infectious disease, or being in contact with a person so suffering to milk cows or handle vessels for containing milk for sale; or
(5) if himself so suffering, or having been in contact as aforesaid, to take any part in the conduct of said trade; or
(6) to permit any water closet, earth closet, privy, cesspool or urinal to be within or communicate with a dairy, milk store, or milk shop; or
(7) to use or permit a dairy, milk store, or milk shop to be used as a sleeping apartment; or
(8) to keep swine in any cow shed or other building used for keeping cows, or in any milk store, or place used for keeping milk for sale.

II. If, at any time, the disease exists among the cattle in a dairy or cow shed, the milk of the diseased cow—

(1) shall not be mixed with other milk;
(2) shall not be used or sold for human food; and
(3) shall not be used or sold for food for swine or other animals unless and until it has been boiled.

Anthrax.

The Local Authority under 'The Contagious Diseases (Animals) Acts, 1878 to 1886,' in virtue of the powers conferred upon them by said Acts and the order of Her Majesty's Most Honourable Privy Council entitled 'The Anthrax Order of 1886' and of every other power enabling them in this behalf, do hereby make the following regulations, viz.:—

I. In these Regulations the words 'Animals,' 'Carcass,' 'Fodder,' and 'Litter,' shall respectively have the same meanings as in the said Anthrax Order of 1886, and the word 'Inspector' shall mean the Veterinary Inspector of the Local Authority.

II. An animal affected with or suspected of anthrax shall not be moved out of any building, field, or other place, except to an adjoining building, field or other place for the purpose of isolation, and that only on the written authority of the Inspector, or, in his absence, on the written authority of the Officer of Police in charge of the Division in which such building, field, or other place is situated, which written authority shall not be granted if the animal, in its movement, is to pass along or across a public highway, or near any other animal or animals not affected with anthrax, and an animal moved for the purpose of isolation as aforesaid shall not be again moved for a period of fourteen days, nor until it has thereafter been declared free of anthrax by the Inspector; and if the animal should die or be slaughtered, the

carcass shall remain untouched until buried or removed under the direction of the Inspector.

III. An animal that has been in contact with or in the same building, field or other place with an animal affected with or suspected of anthrax, shall not be moved out of any building, field or other place in which anthrax exists, except to an adjoining building, field or other place, and that only on the written authority of the Inspector, or, in his absence, on the written authority of the officer of Police in charge of the Division in which such building, field or other place is situated, which written authority shall not be granted if the animal in its movement is to pass along or across a public highway or near any other animal or animals not affected with anthrax, and an animal moved as aforesaid shall not be again moved for the period of fourteen days, nor until it has thereafter been declared free of anthrax by the Inspector.

IV. Any fodder, litter, or other thing that has been in contact with or used for or about an animal affected with or suspected of anthrax shall not be taken out of any building, field, or other place except to an adjoining field or other place approved of by the Inspector, there to be forthwith disinfected, burnt, or destroyed in terms of said Anthrax Order of 1886.

V. The occupier of every cow shed or other place in which an animal affected with anthrax has been kept while so affected, or has died or been slaughtered shall, at his own expense, cleanse and disinfect such cow shed or other place in the manner prescribed by the said Anthrax Order of 1886.

VI. The occupier of every cow shed or other place in which an animal suspected of anthrax has been kept while so suspected, or has died or been slaughtered shall, if so required by the Inspector, cleanse and disinfect the same at his own expense, either in the manner prescribed by the said Anthrax Order of 1886 for cleansing and disinfecting a cow shed or other place in which an animal affected with anthrax has been kept while so affected or in such other manner as the Inspector shall direct.

VII. All utensils, pens, hurdles, or other things used for or about animals affected with, or suspected of anthrax, shall be cleansed and disinfected by the owner thereof at his own expense by being, as far as practicable, thoroughly washed or scrubbed or scoured with water, and thereafter washed over with lime wash to the satisfaction of the Inspector.

Great importance of pure and sufficient water-supply near milch-cattle sheds.—The importance of a pure water-supply near all milch-cattle stalls is a matter of the first importance; though it is desirable that adulteration, even in its least deleterious form, be checked, yet it is still more desirable that such adulteration should be one not likely to carry disease into our houses. All polluted tanks and wells near cattle stalls ought therefore to be

closed and a proper water-supply provided. A native milkman will not go far for his water-supply, and though he may say that he derives the water in general use in his house from a stand-pipe or *pure* water well, such a statement must be accepted with caution; the water from the *nearest* well, impure and foul though it be, will certainly find its way into the milk, the tank into which his cow shed drain discharges, or into which the effluent from his neighbours' latrines flows, the bathing tank of the surrounding population, the tank which has served the wants of his father and his grandfather, that is the place whence water for milk adulteration will probably be drawn. There is, however, a practice in Southern India, which goes far to check the practice of adulteration and that is the practice of driving round the cow; how far that is good for the cow and the milk is another matter, but it is certainly an economic mode of carriage and there is greater certainty of purer milk; if the milkman however is not looked after, he will probably partly fill his measure from a well in the purchasers' compound.

Construction of public cow sheds advisable.—Where such a plan is possible, it is a most advisable one for the municipality to build one or more sets of cow sheds where all the milch cattle may be stabled. These places should be models of their kind and the stalls should be let out at as low a remunerative rate as possible.

HACKNEY STABLES, &c.

Very similar requirements should be enforced in regard to Hackney stables, sheep pens, &c.

PARCHERRIES.

To any one engaged in sanitary work in India the parcherries or bustees are a prominent feature of all towns. The name is usually associated with a collection of huts, cowsheds, pig styes, filthy lanes, gutters of filth and corruption, offensive to sight and to smell. Such places are not only the resting place, but the breeding ground of many of the epidemics which devastate our towns; it is therefore almost useless to say that to such places first efforts in sanitation ought to be directed. Such places cannot unfortunately be got rid of altogether. They are the abode, not only of the lower, perhaps lowest, class of the population, but in these places many of the domestic servants of Europeans and natives also

dwell. Their state, therefore, is one not limited in its effects to their own residents, but to a large surrounding population.

Improvements necessary.—The necessity for improvement should therefore be looked upon as one of the very first importance. No one who reads these pages can doubt for one moment as to what form the improvements ought to take, viz., proper drainage, good water-supply and sufficient latrine accommodation; the widening and straightening of the streets and lanes are no less necessary sanitary requirements.

Procedure for improvement.—Usually it will be found that the ground on which a parcherry stands is the property of one, or perhaps at most, two or three owners. In such cases they can be called upon to aid in the improvement under the various provisions in the Municipal Acts. A proper plan of procedure is first to have a survey of the parcherry made and a plan prepared on a fairly large scale, one which will allow of all the buildings being distinctly shown. The lines of proposed new streets should then be laid down and places selected for the necessary latrines. Compensation must be paid by the municipality to the owners or occupiers of the houses requiring removal to admit of these improvements being carried out; but the owners can be called upon to construct drains and pave the streets; if they fail to do so, the works can be carried out at their expense. In many cases it will be found to be the better plan to pull down and re-erect a whole parcherry. Under these circumstances compensation will be required by all the occupants, and they should be induced to go to some other selected site where the lines of the streets, sites for latrines, &c., have already been marked out. The former site should then be thoroughly dug up, and, if possible, a crop of grass or cholum raised upon it; to allow weeds to grow over it, if nothing better can be done, will also improve the sub-soil of the site.

Advantage to be taken of a fire.—Parcherries from their construction and arrangement are often the scene of fires, and here is a chance for municipal officers to interfere, as huts ought not to be allowed to be rebuilt except under proper regulations.

Regulations under which new parcherries ought to be laid out.—In laying out new parcherry the following rules or similar provisions ought to be insisted upon :—

The streets should be laid out in straight parallel lines, at least 15 feet wide.

A sufficient number of cross streets ought to be provided, at least 9 feet wide, to allow of easy access to all the huts.

If the huts are placed back to back or end to end, there should be no space between them; such places become simply *places d'aisance*. It is, however, better for each hut to have an enclosed open yard right round it.

The floors of the huts should be well raised from the ground not less than 18 inches or 2 feet. The walls should be of brick or mud, well whitewashed; grass roofs ought to be discouraged as far as possible.

Large spaces ought to be left round the latrines and planted with quick-growing trees, shrubs, &c.

The wells * should be far from latrines and also in open spaces surrounded by grass plots if possible; where a pipe water supply is available, it should be laid down to as many places in the parcherry as possible, but always where the waste water can have free exit by drains which should be laid down on principles hereinafter described; but it may be stated that, with a poor class of house, open drains are the only applicable description of drainage. These can be directed towards the main drainage system of the town, and arrangements should be made for flushing them from the wells or taps in the parcherry.

Any tanks in a parcherry should be cleaned out, the banks sloped, &c., and arrangements made for preventing pollution. Such tanks it is well to set apart for washing and bathing only and not for providing potable water.

Suitable sites for parcherries.—The site selected for parcherries ought to be on slightly sloping ground and adjacent to one or two main roads, if possible. The soil should be of a description which will soon dry after rain, *i.e.*, of a porous character.

BURIAL-GROUNDS AND CREMATION.

If the provisions of the Municipal Acts are strictly observed, little nuisance will result from such places. In fixing a site for a burial and burning ground, there are certain points which should be kept in view; these may be summed up as follows:—

1. A burial and burning ground should be far, though not inconveniently so, from inhabited houses; due

* *See* Constructions of Wells, &c.

allowance should be made for the growth of the town, and burial-grounds should be considerably beyond any limits the town may touch even after a quarter of a century.

2. It should be on that side of the town opposite to that from which prevailing winds blow.

3. It should not be near any source of water-supply.

4. The site should be high above flood-level.

5. The soil ought to be of a somewhat stiff, though not too hard, character, free from boulders, rocks, &c.

6. The level of the sub-soil water should be more than 8 feet below ground surface.

Result of non-observance of above conditions.—From grave-yards, where the provisions laid down for their regulation are not observed or where the above conditions or a majority of them do not obtain, vapours tending to produce disease will constantly be evolved and even the best regulated grounds when thickly crowded are fruitful sources of noxious gases.

Digging shallow graves, a practice to be prevented.—The greatest fault observed in Indian grave-yards is the constant effort to evade digging the graves to the proper depth, say, 7 to $7\frac{1}{2}$ feet, and to this fault is due the smells which abound in burial-grounds; it is needless to say that the result to the surrounding populace is an increase in disease, and a death-rate above the normal, the reason often not suspected until the closing of the neighbouring burial-ground and then discovered by the decrease in the mortality in the surrounding district.

Reasons for smells near burial-grounds.—These smells are due to the putrefaction of the bodies, which has been defined as a spontaneous change, common to all nitrogenised organic bodies when exposed to the air, whereby they are resolved into new and simpler products. The action is accompanied by the evolution of unpleasant gases.

Conditions of putrefaction.—As the conditions necessary to putrefaction, viz., air, moisture and warmth, are all present in the burial-grounds of this country, rapid decomposition and rapid air evolution of death dealing gases are the results.

Exposure of corpses a source of disease.—There have been many cases of fever and dysentery brought on by too near an acquaintance with corpses exposed by jackals or dug up again in forming new graves; deep and careful

burial is therefore in India even a greater necessity than in a temperate climate like that of England where the regulations are more strict, where the burial-grounds are really a garden of the dead and not the dreary row of mounds without grass, trees, flowers, or tombstones which is especially the characteristic of native burial-grounds.

Graves ought to be kept ready.—Without constant supervision the regulation of native burial-grounds is difficult, especially as is often the case, when the burials take place at night and when the grave is hurriedly dug after the corpse has arrived on the ground; it is well, therefore, to insist upon the vettians having always a certain number of graves ready dug (except perhaps in monsoon weather). These can then be inspected and the proper depth insisted upon.

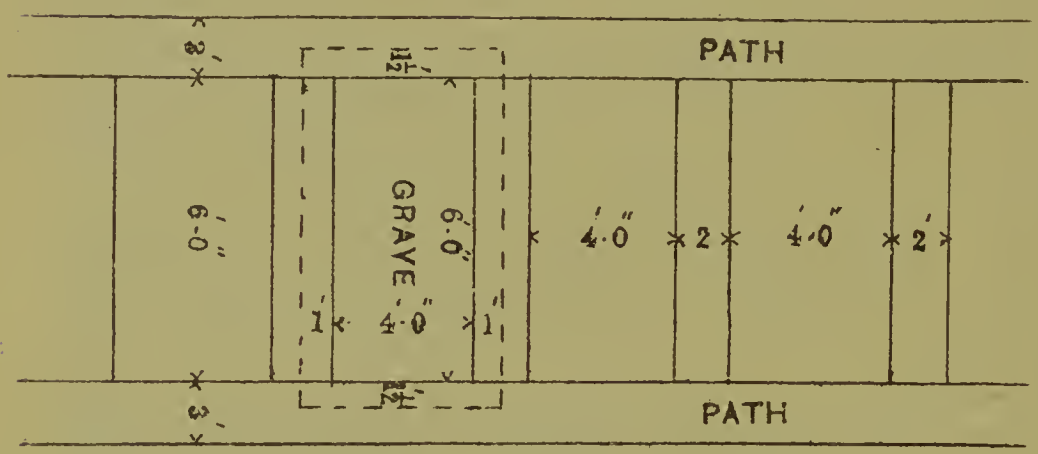
Regulations necessary.—The vettians ought also to be allotted certain portions of the enclosure in which only they ought to be allowed to dig graves until such portion is filled up. The lairs should be marked out at least $6' \times 4'$ with a pathway not less than 3 feet wide at either end and a space of not less than 2 feet between each lair. To number these would be a further improvement, and a ground register showing the date of the last burial in each lair is very desirable.

All graves should remain undisturbed for seven years.—Where land is difficult to obtain and where a ground has once been covered, recourse is usually had to the older undisturbed portions on the ground and the process commenced again. This is a practice extremely undesirable, and in most cases quite unnecessary; even for financial reasons (the only one which can be urged in its favour) it should not be supported. In any case, no grave should be disturbed under a period of seven years, though various authorities have stated that bodies will decay in five and even three years. The period is, however, so dependent on the composition of the soil, its porosity, the sub-soil water level, the amount of pressure, &c., that no hard-and-fast rule can be laid down except this, that the longer a grave can remain undisturbed the better.

Vegetation in burial-grounds to be encouraged.—As the action of vegetation arrests the products of putrefaction by absorption, giving them out in another and harmless form, it is advisable to plant trees, grasses, &c., over the disused portions. In Madras some of the burial-grounds adjoin sewage farms, into which the used up

portions of the burial-grounds are converted and from which are taken many crops of grass, while plantains, guavas and figs grow freely. Guinea grass, lucerne, &c., are also suitable, quick-growing shade trees, such as the rain tree, the sissoo, &c., are recommended.

Area required for burial-grounds.—The space required for a burial-ground is one of easy determination; suppose that the time during which graves are to be undisturbed has been fixed at seven years, that the population is 1,000, that the mortality is 30 per thousand and that the lairs are to be thus:



Then the space appertaining to a lair is $(6+1\frac{1}{2}+1\frac{1}{2})\times(4+1+1)=9\times6=54$ square feet; the space required per annum is $54\times30\times1=1{,}620$ square feet.

To that may be added 5 per cent. for fences, trees, &c., and other portions which cannot be used: there will then be $1{,}620+80=1{,}700$, and for seven years $=11{,}900$ square feet, or a little over $\frac{1}{4}$ acre.

This is a minimum and where ground is not very expensive, about one-half acre per 1,000 persons would be desirable.

Cremation.—Though there are many modes of disposal of the dead, one more only need be referred to, viz., the practice of cremation, a mode of disposal which is one much to be encouraged. There are in Europe many prejudices against this method; but it is rapidly growing in

favour and must bye and bye in larger towns become almost necessary. While some of the reasons against cremation are sentimental, there are other practical reasons relating mostly to jurisprudence. The practice, however, is one which has long been in vogue in India, and though considerable improvement might be made in the manner of carrying it out, the system now practised is not particularly offensive. It is, however, the duty of municipal servants at the burning grounds to see that the corpses are completely consumed, and in those cases where the ashes are not carried away, that they are prevented from accumulating in heaps to the inconvenience of persons attending succeeding ceremonies.

Sale of firewood at burning-grounds. — The monopoly for the supply of firewood to the burning grounds is sometimes sold, but though considerable amounts may be realized, it was found in Madras that considerable hardship ensued from the practice.

The vettians are therefore now allowed to supply the firewood and bratties only when asked to do so, and they are licensed under the following conditions and are limited to the following fees :—

(*a*) This license may be withdrawn or cancelled on proof of the said licensee not being available without reasonable excuse at the said burial or burning ground at any time or times at which his services as vettian may be required by any member or members of the community usually resorting to it ;

(*b*) or neglecting to do the duty usually required of him there as vettian on occasions of burial and burning ;

(*c*) or causing or permitting or being a party to any infringement of the rules laid down in the Muncipal Act as far as they affect him and his duties as a vettian ;

(*d*) or demanding or attempting to exact any higher fee than at the rates following, viz. :—

	A.	P.
For burial of a corpse of or under 12 years of age	8	0
Do. above that age ..	10	0
For cremation of a corpse of or under 12 years of age including the milk ceremony, if any	3	0
Do. above that age, do...	6	0
For supplying tools for the purpose of digging grave, &c., to those not otherwise requiring his services	1	6

(*e*) or being guilty of any misconduct which, in the opinion of the President, requires the withdrawal of the license.

The cost of fuel for cremation in Madras is as follows:—

	Rs.	A.	P.
600 bratties (cowdung cakes) ..	0	12	0
Firewood	0	4	0
Cooly-hire as above	0	6	0
Total ..	1	6	0

During the rainy season the charge for fuel is doubled. If wood alone is used, 240 to 400 lbs. are required, costing Rs. 1 to 2. The cost of cremating paupers in Calcutta is, for adults, Rs. 1–9–6; five maunds (400 lbs.) of wood costing Rs. 1–8–0 are used, and for children under 10 years As. 13–6.

Cremation should be encouraged.—On sanitary grounds, as well as on grounds of economy, cremation should be encouraged.

FAIRS AND FESTIVALS.

The following are the instructions which have been issued in Madras in regard to sanitation at fairs and festivals. They are apparently so complete as to allow them to be inserted without further observation:—

Rules for the Arrangements to be made in the Management and Conservancy of Fairs and Festivals.

I.—Accommodation.

Make suitable provision for the probable number of persons who may not be able to find accommodation in adjacent towns and villages as follows:—

i. Select level, and lay out suitable encamping grounds, bearing in mind the principal requirements of elevation; proximity to place of concourse; sufficiency of a pure water-supply; dry, clean and untainted soil, and direction of prevailing winds.

ii. Lay out this ground in divisions or sections, separated by streets not less than 40 feet wide, and, when space permits, with subsidiary streets 20 feet wide.

iii. Erect upon these sites temporary sheds or huts for the accommodation of those who may require them.

iv. Leave space to the leeward of each section for the carts and cattle of the people occupying each section.

v. As far as possible, assign sections to different castes, indicating each by a legible signboard.

II.—Conservancy.

1. Erect suitable latrines for males and females in number sufficient to meet the requirements of the crowd.

2. Establish separate pits for the burial of (*a*) rubbish and (*b*) filth.

3. Organise a conservancy establishment, according to requirements, for the following purposes :—

(*a*) The removal daily of all rubbish and refuse, including the dung of cattle, from the streets, both of the town and camp, and from the encamping ground generally.

(*b*) The removal of all human excreta from the public latrines and from residences within the town.

(*c*) The disposal of the same in the filth-pits.

III.—Water.

1. Select suitable but distinct tanks, wells, reservoirs or other sources of water-supply—

(*a*) for drinking and domestic purposes,
(*b*) for bathing, and
(*c*) for watering cattle.

2. Obtain a police guard for the source of supply selected for drinking, to guard it from contamination.

IV.—Medical Supervision.

1. Appoint as sanitary officer a medical or subordinate medical officer, whose duty it shall be to superintend the sanitary arrangements generally, to visit the hospitals and places for distribution of medicines, to make himself acquainted with the medical history of the assemblage, as far as possible, from day to day, keeping a return of all deaths reported through the police.

2. Establish temporary hospitals, with suitable establishments, at convenient sites, and in number proportionate to the assembly.

3. Depute medical subordinates to examine at the barriers all travellers coming or departing who may appear to be labouring under sickness.

4. Distribute, through suitable agency and at selected localities, ‘ cholera pills ’ for immediate use by persons attacked with cholera.

V.—Precautions against Accidents.

1. Assign gates for ingress and egress into each town, temple or shrine, in cases in which numbers are considerable, and where instances of loss of life have occurred or may be apprehended from want of due arrangements of this nature.

2. Erect barriers where necessary to prevent the undue influx of people into limited areas fully occupied by devotees, admitting fresh worshippers only as numbers decrease by egress from the opposite barrier gate.

VI.—Police.

1. The local Sub-magistrate to be instructed to bring to the notice of the Sanitary officer all deaths occurring within the limits of the camp or town.

2. Publicity to be given, through the Sub-Magistrate, to the fact that hospitals are established and depôts opened for the distribution of cholera medicines.

3. Notices to this effect to be posted in the vernacular all over the camp and town, and pilgrims, or those frequenting fairs to be instructed to apply for such medicines on the first occurrence of illness.

4. Notices of the arrangements made for the general convenience of the people to be also freely distributed amongst them, and posted upon all conspicuous places.

VII.—Construction of Latrines.

1. Latrines to consist of walled spaces enclosed by walls or tatties in which paralleled trenches should be dug from 1 to 2 feet wide by 3 feet deep. The soil removed from these trenches to be stored at their edges, and a portion daily shovelled in to cover the night-soil.

2. At the termination of the feast, these trenches should be fully covered in.

VIII.—General.

1. Prior to feasts and festivals, chattrams, choultries and grounds generally resorted to by pilgrims as camping or halting grounds to be put by the district authorities into a good sanitary condition, and provision made for a pure water-supply. The same to be maintained in a good sanitary state till after the dispersion of the pilgrims.

2. At the termination of the feast or festival, should cholera have prevailed amongst the people, the halting grounds to be ploughed up, and chattrams and choultries fumigated and white-washed.

Form of Report to be submitted by Medical Subordinates on the Sanitary Condition at important Fairs and Festivals.

1. *Water-supply.*—Its nature and source. Quality good or otherwise. Any suggestions for its improvement. How conserved?

2. *Epidemics.*—What measures taken to prevent or modify?

3. Principal causes of admission to hospital. General health of people.

4. *Conservancy.*—Latrines, how many? If freely used. On what system? Establishment of sweepers, sufficient or otherwise?

5. Recommendations, if any, for management of future festivals.

SANITARY REGULATIONS TO BE OBSERVED ON THE PROBABLE ADVENT OF CHOLERA.

Water.

1. Water is probably the most ordinary means by which cholera is disseminated in a community. It is consequently at all times necessary, but most essentially so when cholera is about, to keep all sources of water-supply as clean and free from contamination as possible.

2. This will best be done by setting aside in all communities, villages as well as towns, certain tanks from which drinking-water alone may be drawn.

3. Over these tanks watchmen should be placed, whose duty it will be to prevent any one washing the body or clothes therein.

4. When drinking-water is drawn from wells, it should be strictly forbidden for people to wash bodies or clothes quite near the well, as is often done, so that the dirty water can easily sink into the earth and find its way back.

5. When rivers or streams are the source of drinking-water, arrangements should be made that cattle, &c., are watered down-stream and the supply for human consumption drawn above.

6. All washing of clothes and persons should, if possible, be prohibited in running streams, for although arrangements can be made by washing down-stream to preserve, say, village A, yet the contaminated water runs on to village B, from the villages above, and thus becomes a source of danger.

7. When cholera is present in a community, it is better to boil all water before using it for drinking purposes.

Latrines.

8. Great care is necessary as to the disposal of fæcal matter. The public latrines should be kept as clean as possible, dry earth

being freely used, and as these places are periodically cleaned, the community should be encouraged to use them instead of holes and cess-pools within their houses.

9. If cess-pools and private privies are used, these should be cleaned out as often as possible and dry earth at all times freely used to cover recent deposits.

10. No cess-pool should be used that is near a well of drinking-water. It should be closed at once.

11. If the latrines are not sufficiently numerous for the wants of the community, temporary latrines with movable tatty walls should be constructed in waste places to leeward of prevailing wind (sketch, plan and estimate of such latrines are given in the Sanitary Commissioner's annual report for 1880).

12. Inside these latrines, trenches, 1 foot wide and 2 feet deep, may be dug, and the earth shovelled in again when the trenches have been used, thus covering the deposits. The latrine walls can then be easily moved on to a fresh place.

When Cholera has supervened.

13. When cholera attacks a community, it generally at first appears in isolated cases, and, if care and attention is paid to prevent its spreading, much may be done to mitigate the severity of the epidemic.

14. The house wherein a cholera case has occurred and its inmates should be, as much as is consistent with humanity, cut off from communication with the rest of the community.

15. Water, food, clothes, &c., from that house should not be taken to other houses.

16. People, except those professionally obliged to, should be forbidden to visit the house until it has been properly disinfected.

17. All clothes belonging to the patient, especially if he has died, should, if possible, be destroyed by fire, or if washed, this should be done with water brought to the house: the clothes should not be taken to the tank for that purpose.

18. All discharges from the patient should at once be removed and buried in pits; if practicable, they should be disinfected. Dry earth, charcoal and ashes are the cheapest and most easily-procured disinfectants.

19. Houses in which cholera has occurred should be disinfected; this may be done by means of sulphurous acid in the following manner: All inmates should be removed, and the doors and windows being closed, pans of burning charcoal should be introduced, and on these a quantity of sulphur powder thrown. The room should remain closed for some hours.

20. After this, the rooms having been opened and ventilated, the walls should be scraped, fresh white-washed, the old earth from the floors removed, and fresh earth used to replace it.

21. In short, *clean* water, *clean* food, the free use of salt, and *cleanliness* generally, are the best preventives against the spread of cholera.

Treatment of Cholera.

22. There is no specific treatment of cholera which can be looked upon with confidence, numberless as are the cures constantly published in the papers generally by unscientific people.

23. The free use of salt has been strongly recommended as a preventive, and there can be no doubt that people deprived of that condiment fall easy victims to this dreadful malady. Salt should always be used with food, and more freely so when cholera is about.

24. Cholera often shows itself first by a premonitory diarrhœa, and people should be encouraged to apply at once, when so suffering, for treatment.

25. Ten to twenty drops of chlorodyne in some spirits and water, repeated in two or three hours (to those who can afford such a remedy), will often cut short such a diarrhœa.

26. Cheaper medicines, such as chalk mixture, Patterson's pills, cholera drops, should be kept at the head-quarters of communities, to be dispensed by some intelligent person when no doctor is available, and much good may thus be done in checking premonitory diarrhœa.

27. When cholera is fully established, professional aid must, of course, when available, be immediately procured. It would be useless to lay down any general rules for treatment under such circumstances.

THE DHOBIE.

Existing conditions.—The dhobies are accustomed to wash the clothes of their employers in shallow streams, pools, tanks and wells, the latter usually pot wells and not very deep. The wells are made of earthen rings placed one above the other as the well sinks. The stones on which clothing is beaten are within a few feet of the wells. No drains are provided and the water used usually soaks back into or towards the well. The houses of the dhobie class are, as a rule, more cleanly than those of the lower classes of the community. The clothing to be cleaned is usually stored in a dhobie's house side by side with that already washed, and it may be easily understood that during an epidemic a great means of spreading it exists. The dhobie is, however, probably more sinned against than sinning, because very often clothes which have been used by patients suffering from an infectious disease are sent to the dhobie without warning and without having been previously disinfected, and thus not only is disease introduced amongst the dhobie community,

but that community becomes a centre for the spread of the disease to others.

The foregoing are practically the remarks of Dr. W. G. King, Sanitary Commissioner of Madras, who makes the following proposals to mitigate, if not prevent, the evils referred to above:—

(1) The storage of clothing in the private dwellings of dhobies should be discouraged.

(2) Endeavours should be made to place such conveniences at the disposal of dhobies that they should be led to settle in the same quarters of the town whence they chiefly derive their work. This would do much towards limiting the spread of disease.

(3) Cleanliness should be ensured in the process of washing, as well as correct hygiene of the locality in which it takes place.

To meet these ends, all professional dhobies should be classified into two grades and be allowed to pursue their vocations subject to licenses, issued without fee, by the municipality. The conditions under which these should be granted should be that the house, the source of water-supply, and the place of washing and drying be primarily approved, and shall subsequently be retained in a state that will satisfy ordinary sanitary requirements; and, secondly, that it be compulsory that a list be kept by each, showing the names and residences of their employers. This arrangement is probably all that could be done for sanitarily regulating the actions of average dhobies, both on account of their poverty and habits, and the status of the people for whom they work.

As to the second grade more, however, might be accomplished. In large towns it is impossible that there should not be a considerable section of their community that would gladly pay for the support of wash-houses under good management. To suit the convenience of such persons, it is suggested that the erection of ranges of buildings consisting of separate, small, well-ventilated rooms destined solely for the storage of dirty clothing, and others jointly for storage of clean clothes and for the process of ironing. There would be no difficulty in arranging for the safe custody of such places. The buildings should be erected in various parts of the town. In proximity to each should be sufficient open ground for drying and bleaching purposes. Abyssinian tube wells, or the ordinary cylinder wells of the country, would yield a safe supply of water if the towns supply could not be spared. A very little management would, without interference with the dhobie's traditional habits, secure the placing of an impervious flooring, the use of separate water by each man, and its removal by effectual drainage. The whole washing operation should be conducted in the open air. A municipality might start such wash-houses under their own supervision the first year, and subsequently let them out on

contract. Payments for rent of wash-houses should be made by the dhobies, who would doubtless recover the amount by higher charges to their employers. In connection with this point I may state that dhobies at certain places pay owners of ground at the rate of one rupee per mensem to be allowed to use it for drying purposes.

Such suggestions would, of course, not cover the danger of persons sending infected clothing to the wash. Here legislation should interfere, by making the careless disposal of choleraic matter penal, taking care that proof of knowledge of danger be not necessary, as such proof is at all times difficult to obtain; discretion given to magistrates would sufficiently guard against undue harshness. A well-organized sanitary staff dealing with such matters, and fitted with convenient arrangements for the public to give effect to sanitary precautions, should also be a *sine quâ non*. To the sanitarian, if not humanitarian, it must remain a puzzle when laws are called into force to regulate and control the storage of gunpowder, dynamite and kerosine that the evident peril which may result to the lives of thousands from the careless disposal of disease-bearing matter should be ignored.

The diagram on the succeeding page is from a rough draft of a design for a dhobie-khana by Dr. King.

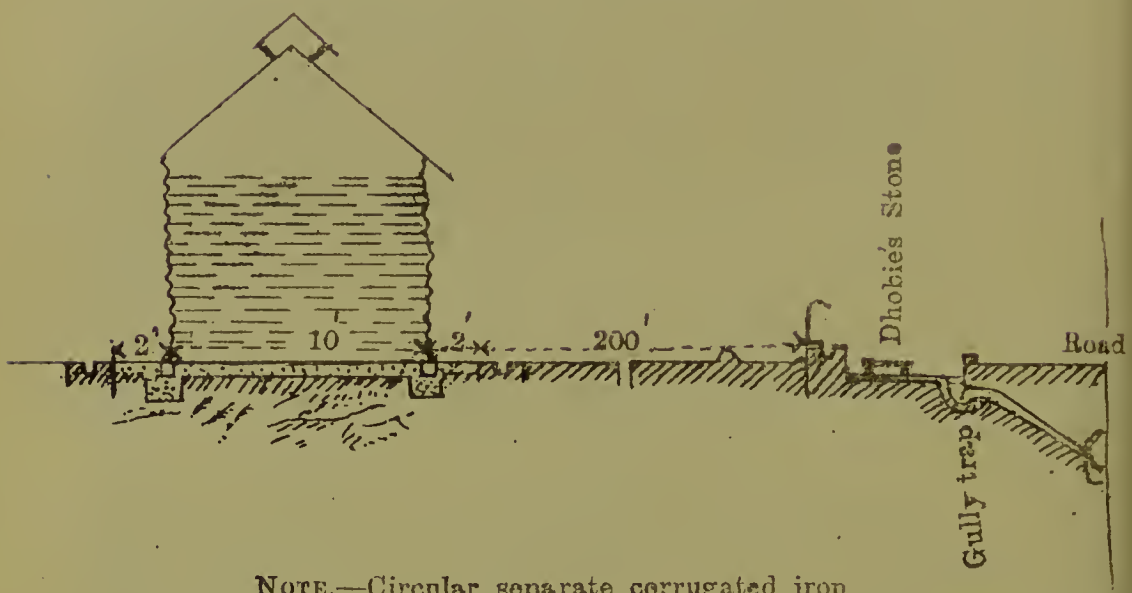
Bakeries.—Bakeries are also places which require supervision. There is enough reason for this when two coolies are seen reeking with perspiration sitting up to their knees in the flour they have just ground probably with betel leaf in their mouths, the contents of which are ejected from time to time, *whither?*

Tanneries.—Tanneries are most offensive, and the chief requirement in regard to them is that certain hours should be fixed, during which alone the hides and skins may be drawn from the tan-pits. It is well to keep them outside the town.

Paddy-boiling.—Boiling paddy is another occupation worthy of constant inspection. The same water is apt to be used again and again, probably water very far from pure in the first instance; paddy boilers ought to be limited to wells of known purity for their supplies.

Other trades.—The refuse from oil-boiling houses, dye houses, &c., should not be allowed to fall into the street drains. Brick-kilns ought to be fired only during certain hours. Lime-kilns ought to be at a distance from public roads; the storage of bones, horns, &c., should never be permitted adjacent to dwelling houses. Trades, such as indigo-dyeing, soap-boiling, &c., which are particularly offensive, ought to be relegated to the outskirts of a town.

HALF SECTION OF DHOBIE-KHANA



NOTE.—Circular, separate corrugated iron huts 10' dia.; interior painted with white silicate paint.

The hut on one side is for clean clothing, the other for foul clothing.

CHAPTER III.

CENSUS, REGISTRATION AND VITAL STATISTICS.

CENSUS AND REGISTRATION.

Census.—A census may be defined as the collection of correct vital statistics. Vital statistics must be considered, *firstly*, in relation to the source and collection of information, such as taking a census, registration of births, deaths, &c.; *secondly*, in regard to the results so obtained when these are properly tabulated.

To obtain correct vital statistics, it is essential to have (1) a correct enumeration of the population, (2) a complete and accurate registration of births, marriages and deaths, (3) an accurate statement of the age, sex and cause of death of each person.

The actual population is known at the date of each census only. During the intervening years, estimates of the population are made. The requirements of a good census, from a sanitarian's point of view, are, that the enumeration shall be accurate, complete, rapid and simultaneous throughout the country to avoid the disturbing influence of migration. The particulars required in the last Indian census (1891) were as follows :—

(1) Serial number and name.
(2) Religion.
(3) Sect of religion.
(4) Caste of Hindus and Jains, tribe or race of others.
(5) Sub-division of caste, &c.
(6) Male or female.
(7) Age.
(8) Married, unmarried or widowed.
(9) Parent tongue.
(10) Birth district, province or country.
(11) Occupation or means of substance.
(12) Learning, literate or illiterate.
(13) Language known by literate.
(14) If any person be insane, deaf-mute from birth, totally blind or a leper, enter that person as such.

A continuous system of registration of births, deaths, &c., however perfect, cannot take the place of a 'census,' in so far that it gives no record of emigration or immigration which are powerful factors, especially in large seaport towns or towns, with special industries, in varying the respective classes and number of the population. A census, therefore, is a necessity, and it is usually taken every ten years. The results are especially valuable to municipal officials, the more so if the results are specially tabulated so as to show the population in each street, district and parcherry and the density of each such division.

Before a census is commenced most elaborate instructions are issued by the Government of India and the Local Governments; but, while keeping strictly to these rules, it is always open to Municipal Councillors, who in towns supervise the operations, to obtain such additional information as will assist in the preparation of municipal statistics.

A description of the preliminary operations in the City of Madras preparatory to the last census will be found at the end of this chapter.

Estimation of population in intercensal period.—Estimates of the population require to be made in the interval between each census and the one immediately succeeding it. If the number of births, deaths, and the amount of immigration and emigration since the preceding census were known, the estimation would be easy, but registration is never perfectly correct, and the amount of immigration and emigration can only be roughly determined.

The Registrar-General's method of estimating the population is based on the assumption that the same *rate of increase* will hold good as in the previous intercensal period. For small towns, however, it is sufficiently correct to add one-tenth of the actual increase shown at the last census; in large towns this plan would lead to a considerable error. By such plan no notice would be taken of the increase of population which would ensue from the annual increment.

The proper plan to obtain the population of a place for any given year in the present decade is this—find the logarithms of the last two census returns, and subtract the lesser from the greater; this will give the logarithm of the annual rate of increase for the last decade which, multiplied by the number of years since the last census and added to the last enumerated population, gives the estimated population for the year in question, or thus :—

Let a = population in 1881.
b = do. in 1891.
D = { b—a (supposing the population increasing).
a—b (supposing the population decreasing).
$\frac{D}{10}$ = annual increase or decrease.

Then, assuming the population is increasing or decreasing in the same ratio as in the last decade, the logarithm of the population in the year 1895 or four years after the census

$$= \log. b \pm 4 \left(\frac{\log. D}{10}\right).$$

Demolition of property, the opening of new hospitals, immigration and emigration tend to vitiate results to some slight extent.

Registration.—Next to a correct enumeration of population, the accurate registration of births, marriages and deaths constitutes an essential basis of vital statistics. By careful and accurate registration, the limits of mortality and its causes may be determined with some precision and a knowledge also obtained of those causes which bring about a high death-rate.

Registration in India defective.—In India at present only births and deaths are registered, and it cannot be disputed that registration is extremely defective, more so, of course, in the districts than in the towns.

Difficulties in obtaining information.—While it is easier to record births than deaths, fewer facts regarding a birth than a death being necessary, yet it is proportionately more difficult to obtain the necessary information. The registrar is usually dependent on the native midwives, who habitually attend confinements, and on the fact that, when a birth occurs, margosa leaves are placed over the doorway. These midwives, generally of the Ambattan or Barber caste, are without proper training and cannot usually either read or write. There is no doubt that, in towns at least, they ought to be brought under proper control and licensed, and punished if they act without such license. The day has not yet come (though perhaps not far off) when it will be possible to prevent uncertificated persons practising that occupation.

Difficulties in registration of death particulars.—Greater difficulties are encountered in registering the particulars of deaths, and it seems very advisable that no burial should be allowed without a certificate of the cause of death from a medical man of some grade or other. At present no

such measure is in force, and the registrar is entirely in the hands of perhaps an ignorant cooly who comes to register the death, but knows nothing of the cause. Each death is, however, ascertained to have taken place, as there is the check at the burial-grounds (where concopillays should always be on duty), and when once the fact of death and the late residence has been ascertained, it depends on the acuteness of the registrar to register the cause of death correctly or otherwise. Often, however, the deceased persons have not been attended by any medical man, and the classification of the cause of death may or may not be correct.

Mofussil registration not reliable.—While such a state of things exists in cities, in the mofussil matters are very much worse, and the registration returns, so far as their details go, must, of course, for the present, be looked upon with considerable suspicion.

The registration of the cause of death has given much impetus to sanitary work; it is not too much to say that modern sanitary science owes its existence to the registration of deaths and their causes, our knowledge of all the facts of health and disease having obtained a precision it never did before. Yet, as before pointed out, the correctness of the stated cause of death is, in this country, open to much suspicion.

A perfect medical registration of causes of death can only be insured by steady but unceasing steps to that end and by such means as undernoted:—

(1) Improved education of practitioners and others attending the poor.

(2) The appointment of skilled sanitarians as registrars who could gauge the value of information tendered and inquire into dubious cases.

(3) A uniform nomenclature of diseases.

This last necessity is very obvious, or any classified results must be untrustworthy.

The following is the Registrar-General's classification of causes of death:—

I. Specific febrile or zymotic diseases—

1. Miasmatic diseases—

Small-pox .. { Vaccinated. / Unvaccinated. / No statement.

Chicken-pox.
Measles.

Epidemic rose rash.
Scarlet fever.
Typhus.
Relapsing fever.
Influenza.
Whooping cough.
Mumps.
Diphtheria.
Cerebro-spinal fever.
Simple and ill-defined fever.
Enteric fever.
Other miasmatic diseases.

2. Diarrhœal diseases—
   Cholera.
   Diarrhœa, dysentery.

3. Malarial diseases—
   Remittent fever.
   Ague.

4. Zoogenous diseases—
   Hydrophobia.
   Glanders.
   Splenic fever.
   Cow-pox and other effects of vaccination.

5. Venereal diseases—
   Syphilis.
   Gonorrhœa, stricture of urethra.

6. Septic diseases—
   Phagedœna.
   Erysipelas.
   Pyœmia, septicœmia.
   Puerperal fever.

II. Parasitic diseases—
   Thrush.
   Other diseases from vegetable parasites.
   Hydatid disease.
   Other diseases from animal parasites.

III. Dietetic diseases—
   Starvation, want of breast-milk.
   Scurvy.
   Intemperance { Chronic alcoholism. / Delirium tremens.

IV. Constitutional diseases—
   Rheumatic fever, rheumatism of heart.
   Gout.
   Rickets.
   Cancer.
   Tabes mesenterica.

Tubercular meningitis (acute hydrocephalus).
Phthisis.
Other forms of tuberculosis, scrofula.
Purpura, hæmorrhagic diathesis.
Anæmia, chlorosis, leucocythœmia.
Diabetes mellitus.
Other and undefined constitutional diseases.

V. Developmental diseases—
Premature birth.
Atelectasis.
Cyanosis.
Spina bifida.
Imperforate anus.
Cleft palate, harelip.
Other congenital defects.
Old age.

VI. Local diseases—
Diseases of nervous system.
Diseases of organs of special sense.
Diseases of circulating system.
Diseases of respiratory system.
Diseases of digestive system.
Diseases of lymphatic system and ductless glands.
Diseases of urinary system.
Diseases of organs of generation
Diseases of parturition.
Diseases of organs of locomotion.
Diseases of integumentary system.

VII. Violence—
Accident or negligence.
Homicide.
Suicide.
Execution.

VIII. Ill-defined and not specified causes—
Dropsy.
Debility, atrophy, inanition.
Mortification.
Tumour.
Abscess.
Hæmorrhage.
Sudden deaths (causes unascertained).
Other ill-defined and not specified causes.

It is evident that the above classification cannot be made use of in this country with any perfect accuracy so long as persons who undertake the duties of registrars are not all medical practitioners, and it shows how necessary it is that such persons should be so if medical certificates were required in all cases of death.

Particulars required in registration of births and deaths.—The Municipal Acts clearly define the duties of registrars. The Madras Municipal Act, in addition, prescribes the form in which the registration is to be made; the District Act leaves the form to be prescribed by the Governor in Council. The following are the particulars required under the former Act:—

*Births in the District of*_____

Number.	When born.	Nationality or caste.	Name, if any.	Sex.	Name of father.	Profession of father.	Signature, description, and residence of informants.	When registered.	Signature of Registrar.

*Deaths in the District of*_____

Number.	When died.	Nationality or caste.	Name.	Sex. Age.	Profession.	Cause of death.	Residence at time of death.	Residence previous to last illness.	Signature, description and residence of informants.	Signature of Registrar.

VITAL STATISTICS.

Vital statistics defined.—One definition of vital statistics is 'the science of numbers applied to the life history of communities and nations,' another 'that branch of statistical science, which has for its object the discovery of the laws which govern the physical condition of mankind.' This object can be attained only by the consideration of the various problems connected with the birth, life and death of *man*. For their elucidation dependence must be placed on a series of numerical units (the term used by Dr. Parkes) which have to be grouped together, and these numbers must therefore

be all of the same nature and comparable one with another so as to admit of their addition and classification.

'Man.'—It is very necessary to understand correctly the significance of the word '*man*' used in the last paragraph, because it is only by a correct appreciation of such significance that the principles which underlie the science of statistics can be comprehended.

General laws discoverable by the consideration of a large number of units and by losing sight of man as an individual.—General laws are discovered only by the study of phenomena extending over a large number of instances; and by studying the statistics relating to a very large number of individual men, results can be arrived at which allow the promulgation of general laws. M. Quetlet says, in an essay on 'the Development of the Faculties of Man,' 1869; "we must before all, lose sight of *man* taken by himself and consider him only as a fraction of a species. In stripping him of his individuality we shall eliminate all that is merely accidental; and the individual peculiarities which exercise little or no effect on the mass will be effaced of themselves and permit us to lay hold on general results."

System of life assurance based on the expectation of life.—As for example the length of the life of any living individual cannot even be guessed at, yet of any class of individuals what is called the expectation of life, is known and upon such expectation is based the whole system of life assurance.

The uses of vital statistics are exceedingly numerous. In the first place they afford valuable information as to the health of the people and the conditions which influence it for good or evil. By their aid the birth-rate, the death-rate, the mortality from different diseases in different places can be studied. By their aid also is discovered the mean age at death, the mean duration of life, the expectation of life or the mean 'after lifetime' (Farr), the effects of various occupations on health, and the death-rates among the various classes of the population.

Careful preparation of statistics necessary.—Great care is necessary in the preparation of statistics, and it is a rule that, where there is doubt about any death having occurred from a particular disease, it is better to omit such death from the heading to which may be presumed to belong and to group it with undetermined diseases. It must be remembered that statisticians do not attempt to check the figures placed before them; they simply accept them. In

using statistics, however, for the deduction of conclusions even greater caution is necessary than in their preparation; many startling results have been found to be due no less to incorrect statements than to unscientific inferences.

Arrangement of statistics.—In compiling statistics the first thing to do is to arrange the items or numerical units into groups. These numbers are then further divided according to age, nationality, religion or still further according to the weeks, months, division of the town or village in which they occurred.

Comparison of groups.—The classification having been made, the groups have next to be compared with the total number of units taken collectively, and also with each other. The standard universally adopted in vital statistics, in making such comparisons, is to state this relation as per thousand or per ten thousand or per hundred thousand. This is effected thus: suppose a population of 400,000 with the number of deaths in a year, say, from diseases of the nervous system amounting to 4,750;

$$400{,}000 : 100 :: 4{,}750 : 1{\cdot}187$$

and thus 1·187 is the percentage of the population, who died in the selected year from nervous diseases. Again suppose the total number of deaths in the same year was 14,000; now if it is desired to determine what percentage of the total deaths was due to nervous diseases, the calculation is made thus:—

$$14{,}000 : 100 :: 4{,}750 : 33{\cdot}93$$

or 33·93 per cent. of those who died in that year from nervous diseases.

The above are simple proportions, but if (n) be supposed to represent the smaller number and (N) the larger number, it will be seen that the result (x) will be

$$x = \frac{n \times 100}{N}$$

and if the number per thousand is required then

$$x = \frac{n \times 1{,}000}{N}.$$

Mean results.—When several groups have been collected, say those of the percentages of deaths from nervous diseases for ten past years, it becomes necessary to find the mean. This is best effected by adding the totals of all the years together, in this case ten, and dividing by ten, the result is what is called the arithmetical mean. Now suppose the percentages to have been 28·00, 28·10, 27·98, 27·94, 27·80, 27·30, 27·85, 27·00, 26·90, 26·78; The addition of these figures gives 275·65 and divided by 10 is equal to 27·565,

which is the mean percentage of the deaths due to that cause in the selected ten years.

Future figures cannot be accurately derived from results of past years.—If the death-rate figures of each year of ten are taken and treated similarly, the mean death-rate for these ten years can be determined. Now it might be supposed that because the mean death-rate of the preceding ten years is known, it may be applied to the succeeding ten years, but this is not so. Apart from other considerations, such as increase in population, &c., arithmetical means are reliable only when dealing with extremely lengthy periods as will be seen in the following illustration.

Probable or mean error.—Suppose the death-rate of a town during ten years had been per thousand 30, 31, 29, 31, 30, 29, 28, 27, 26, 27, or a mean of $\frac{288}{10} = 28{\cdot}80$. Now the average of the first two years is 30·5, of the second pair 30, of the third pair 29·5, of the fourth 27 5, and of the last 26·5. None of these therefore approach the true mean for the ten years; so similarly the mean of one period of ten years cannot be depended upon as likely to be the mean for the next period. But the greater the amount of the units taken, the more nearly will their average approach the truth. The amount of departure from the average within which, on one side or the other the truth exists, is called the probable error of the arithmetical mean. To find this probable error, from the mean of the series of observations, deduct the mean of all observations which are below the mean and from the mean of all observations above the mean, deduct the mean itself, half the total of the two quantities thus found is the mean error. For example the mean of all observations is 28·8; from this deduct the mean of all observations below the mean, viz., $\frac{28+27+26+27}{4} = \frac{108}{4} = 27$, then deduct 27 from 28·80 and the result is 1·80. Again from the mean of $\frac{30+31+29+31+30+29}{6} = 30$, deduct 28·8, this equals 1·20; add 1·80 and 1·20; half of this or 1·5 is the probable error. The true mean will be between 28·80—1·50=27·3 and 28·80 + 1·50=30·3.

Raddicke's method.—In view to obtaining a close approximation to the truth in calculations made with a moderate number of units, a method sometimes, but perhaps now seldom, used is one which has been called by Professor Raddicke, the method of successive means. Taking the same eries of death-rate figures, the successive means are found thus—

$$\frac{30+31}{2};\ \frac{30+31+29}{3};\ \frac{30+31+29+31}{4}\ \ldots\ \text{&c.,}$$

if we add these successive means thus found, we will have a total of 267·84 and this divided by 9, the number of means gives the figure 29·76. Take again the means in the reverse order, that is thus—

$$\frac{27+26}{2};\ \frac{27+26+27}{3};\ \frac{27+26+27+28}{4},\ \text{&c.,}$$

and add the results; this will be found to be 249·53, and this divided by 9 gives 27·72. We may therefore conclude from these results that the true mean lies somewhere between 27·72 and 29·76, which are rather narrower limits than those found under the former method. One important point in connection with the calculation of averages must be remembered, and that is that if an average of averages be taken, the units comprising each set of averages must be equal, or incorrect deductions will be arrived at.

Published weekly results calculated on an annual basis.—In publishing the numbers of births or deaths these, though published, say, weekly, are still given as so many per annum. Thus if the number of deaths in a town, say, of 400,000 inhabitants was 200 per week we require to know how many per 1,000 or per 100 this is per annum. Now if this rate of 200 per week were maintained in 52 weeks or one year, then $200 \times 52 = 10{,}400$ would be the result; and $\frac{10{,}400 \times 1{,}000}{400{,}000} = 26$ per 1,000 as the death-rate for that week. There are, however, 365·24226 days in a year, so a week is $\frac{1}{52{\cdot}17447}$ of a year. The estimated population should, therefore, be divided by the denominator and the number of births or deaths in a week applied to that figure when preparing weekly returns, thus $\frac{400{,}000}{52{\cdot}17447} = 7{,}666$. This is called the weekly population of the town and the correct death-rate $= \frac{200 \times 1{,}000}{7{,}666} = 26{\cdot}09$.

Comparison of rates for different periods.—In comparing the birth or death rates of one period with those of another, the variation in the numbers of the population must be taken into account. Now, for example, to compare the vital statistics of a town in 1887 with those of the same town in the previous ten years; suppose that, in the week dealt with the number of deaths was 230 and that the average of the corresponding week of the previous ten years was 220, is it to be supposed that the deaths are 10 above the average?

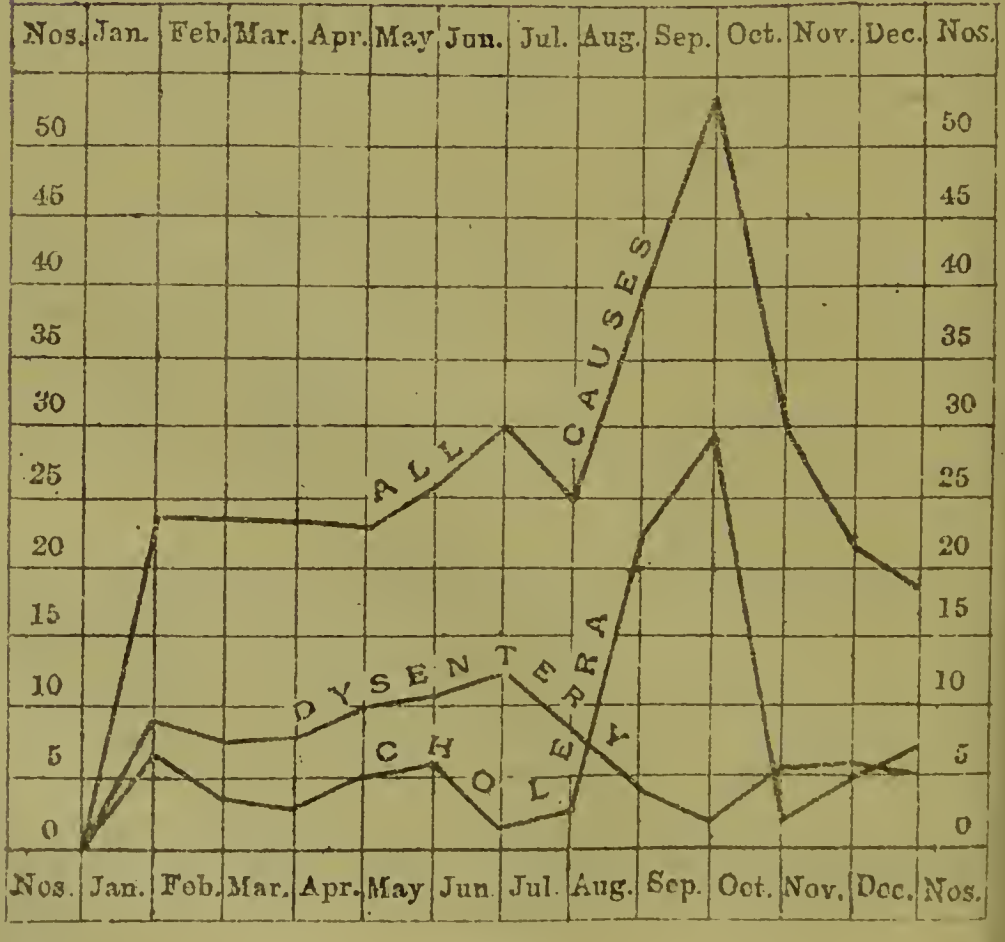
This would be true if the population had not increased, but if by the birth-rate and census returns it was estimated that, in the ten years, the average population had risen, say, from 400,000 to 420,000, we have the proportion—

400 : 420 : 220 : 231

so that in fact the death-rate is below the average and not above it.

Diagramatic representation of statistics.—It is a practice to represent statistical facts on a diagram ; a certain space in one direction on the diagram representing a number and a space in a direction at right angles to the former a division of time. The vertical lines show periods and horizontal particular number while the position of the wavy lines shows the number of deaths which occurred in each period. The use of such a representation is to present the year's figures to the mind at a glance.

DIAGRAM OF DEATH-RATES IN A TOWN OF ABOUT 10,000 PEOPLE.



Birth-rate.—By *birth-rate* is meant the proportion of births which take place in each year when compared with the total population of the district. It is usually stated as so many per thousand of population.

High birth-rate indicative of prosperity.—A high birth-rate usually indicates that a community is prosperous, and a high birth-rate combined with a low death-rate shows that the conditions under which the population lives is favourable to longevity; because the more numerous the births to a marriage the greater is the presumption that a long interval exists between the mean period of marriage and the mean period of death. A high birth with a high death-rate may occur in poor and improvident communities where people marry whether they can afford it or not.

Legitimate and illegitimate births.—In India no distinction is made in the registration of legitimate and illegitimate births, and thus by the birth-rate the prolificness of marriages cannot be judged but from it may be estimated that of the country at large. Most of the influences which are at work in European countries and which cause illegitimacy to be more or less a burden to the State are, in India, absent; it is unlikely that for many years yet to come, Indian statistics will show one class of births apart from the other.

Male birth-rate higher than female rate.—It is a matter of general observation that there are more males born than females, and the proportion in Madras ranges between 109 and 102·6 * of the former to 100 of the latter. In Great Britain it is 103·7 to 100. The mean for Europe is 106 to 100, but it seldom falls below 105 to 100.

Effects of seasons on birth-rates.—The seasons have considerable effect on the birth-rate; in England, the birth-rate is higher during the first three months of the calendar year than in the latter portion of the year. In Madras City (it is regretted that India cannot be spoken of generally) the highest birth-rates occur amongst Hindus, Native Christians and Eurasians between July and October and part of November, and represent conceptions taking place in the months of November, December, January and February, or in the Tamil months Kartikai, Margali, Tai and Masi, the latter being the favourable and lucky months for marriage. These periods are not so marked among

* Census figures of 1891.

Native Christians and Eurasians as among Hindus generally, but their births show the same tendency to fluctuation, race customs (so says Dr. R. E. Davis, late Health Officer of Madras) having left an impress that neither change of religion nor infusion of foreign blood can entirely eradicate. The yearly maxima and minima periods in regard to Mahommedan births exhibit no fixed period.

Still-births, though not registered in the United Kingdom, are so in India; it is believed that in England the proportion is about 4 per cent. of all the births. The ratio of still-births to 1,000 births in Madras in 1890 was 30 per 1,000 or 1 in 33; this is about 1·3 per 1,000 of the total population. The number of still-births is greatest among the Mahomedan population, where the rate at the same date was 37 per 1,000 births and 1·5 still-births per 1,000 of population.

The death-rate is contingent on very many causes, such as place, climate, condition, sex, age, age distribution, sex distribution, scarcity, famine, pestilence and war.

Mortality of males as compared with females.— The mortality of males is usually higher than that of females; in England, about 103 males to each 100 females. It must not be forgotten that the female population is larger than the male population; having regard to this fact, it has been calculated that out of equal numbers of each, about 112 males die in proportion to 100 females. The mean result over the whole life is in favour of female life.

The mean duration of life is the expectation of life at birth; at any other age it is the expectation of life at that age (as taken from a life table) and added to the age (Parkes). It is perhaps better described by Dr. Farr, who says, it is the mean time which a number of persons at any instant of age will live after that instant.

The probable duration of life is the age at which a given number of children born simultaneously will be reduced to one-half the number.

The expectation of life is the true test of the health of the people. Life tables showing such expectation, (on these tables Assurance Companies depend in fixing their premiums, accepting life risks, &c.) are framed in two ways, (1) by a comparison of the deaths and of the living at each age, which gives the rates of mortality and survivorship, (2) from deaths alone or with reference only to the ages at which the deaths take place. The former is the more correct

method. The expectation of life in England, as given in the following table, is by Parkes; the figures referring to native life are taken from the tables computed for Madras by Messers. Stokes and Stuart.

Expectation of Life or Mean Life time from the Ages in column 1.

Age.	Europeans. In England (Parkes).		Native life.			
			Madras Presidency (Stokes), 1881.		Madras City (Stuart), 1891.	
1	2	3	4	5	6	7
—	Males.	Females.	Males.	Females.	Males.	Females.
0 ...	39·91	41·85	28·72	29·52	24·40	24·66
1 ...	46·65	47·31	33·91	34·13	33·51	32·30
2 ...	48·83	49·40	35·17	35·19	37·00	35·04
3 ...	49·61	50·20	35·77	35·71	38·46	36·28
4 ...	49·81	50·43	36·09	36·06	39·32	36·87
5 ...	49·71	50·33	36·20	36·22	39·68	37·06
10 ...	47·05	47·67	34·23	34·50	38·02	35·55
20 ...	39·48	40·29	27·36	28·33	31·90	30·40
30 ...	32·76	33·81	21·76	23·37	26·03	25·84
40 ...	26·06	27·34	16·64	18·30	20·14	20·76
50 ...	19·54	20·75	11·96	13·09	14·48	15·01
70 ..	8·45	9·02	8·48	8·46	9·77	9·66
80 ...	4·93	5·26	7·15	6·73	6·37	5·31
90 ..	2·84	3·01	4·93	4·33	3·61	2·76
100 ...	1·68	1·76	1·76	1·69	1·76	1·50

Expectation of native life lower than that of European life.—It will be observed how much lower is the mean expectation of life in India as compared with European life in England, except after the age 70, when the expectation is higher; this latter fact may be due to the comparatively small number of natives living after that age, and their numbers not affording a sufficiently accurate basis of calculation. The general results are nevertheless very striking, and show by how much the life of *man* in this Presidency may be lengthened when complete systems and proper methods of sanitation become the rule and not the exception.

Formula for calculating expectation of European life.—A formula based on European life tables for determining the expectancy of European life at any age (n) is:—

$$n = \tfrac{2}{3}\,(80 - n)$$

or, suppose the present age 40, then

$$n = \tfrac{2}{3}\,(80 - 40) = 26 \text{ years.}$$

For native lives the formula is not applicable.

From the life tables, out of each 100 children born in

England.		Madras City.	
		Males.	Females.
15	die in the first year	29	26
5	die in the second year	12	10
3	die in the third year	6	4
2	die in the fourth year	3	3
1	die in the fifth year	2·5	2·5
26		52·5	45·5

The density of population, that is, the proportionate number of persons per square mile or per acre, has a material effect on the death-rate. In the more densely-populated places the death-rate is comparatively higher. Of all the influences, however, which affect the death-rate, none are more powerful than sanitary arrangements, and, as pointed out in the introductory chapter of this work, it is these which must be improved to lower the death-rate.

Population, specific and absolute.—The number of the inhabitants of a district, country, or town may be expressed in two ways, *first*, as the numerical total of the individuals; *secondly*, as so many persons to a unit of area, as an acre, square mile, &c. The latter is called the specific population, the former the absolute population. It has been pointed out how intimate are the relations between public health and density of population. An increase of population depends on an excess of births over deaths and emigration; it is more or less rapid according to the prosperity of a community.

Laws of Malthus in regard to increase of population.—Malthus, a philosopher, who wrote towards the close of the last century, enunciated the following doctrines: (1) that population cannot increase without means of subsistence, (2) that the population invariably increases where such means exist, (3) that the superior power of population cannot be checked without misery or vice and that population is increasing in a geometrical progression and subsistence only in an arithmetical progression. He also stated the population doubles itself if unchecked in a period of 25 years. These latter statements are incorrect; Malthus omitted to take into account that, at child-bearing ages, a large proportion of the population is unmarried and virtuous. The birth-rate in

England is 30 per 1,000, the death-rate 19 per 1,000, so that the population doubles itself in 63 years only, but money at 3 per cent. compound interest will double itself in 24 years. Malthus also lost sight of the fact that besides the natural produce of the earth, there is the produce created by human industry. His insistence that the increase of mankind is the chief source of misery and that repression of population is necessary for human happiness is of serious import to the sanitarian, for it would lead to a relaxation of those efforts now being made to improve public health. An increased mortality, in no manner, means decreased population, for the fact is that a high mortality is almost invariably accompanied by an increased birth-rate. War, famine and pestilence are checks on increase of population, but only temporarily so and very often these very checks are the causes of very rapid after increases of the population.

Variation of specific population.—The specific population varies much in different countries; in Belgium 445, United Kingdom 259, Italy 243, Germany 196 per square mile. In towns, the 'specific population' is more particularly called, the density; the following towns show a 'density' per acre as follows:—

London	45·10	Birmingham ..	43·00
Glasgow	100·40	Madras ..	27·00
Dublin	31·30	Bombay ..	55·00
Edinburgh ..	47·80	Calcutta ..	111·70

These figures are, however, very misleading, as, for instance, in all large towns there are immense spaces without any inhabitants upon them, and the density of the remaining inhabited portions of the town is therefore much increased.

Madras, for instance, has in some parts of it a density of 310 per acre, or between eleven and twelve times the average density of the city. To such spots should great attention be directed. A high death-rate and a high density are usually concurrent facts.

DETAILS OF CENSUS OPERATIONS IN MADRAS, 1890–91.

(*Mr. R. E. Ellis, Engineer, Madras Municipal Commission.*)

The first steps in the arrangements for carrying out the census consisted in dividing the divisional map into blocks, each block containing from 60 to 500 houses. These blocks were then outlined on the map with five different colours and

so arranged that no two blocks coloured alike came next to each other.

The maps were then given to overseers with the following instructions :—

The eight divisional maps of Madras have been divided into blocks, containing about 60 houses as far as could be judged.

Each block has been outlined with a distinctive colour, and for the purpose five colours have been used—black, brown, yellow, blue and green. It will be noticed that no two blocks of the same colour are together.

For painting the figures stencil plates have been cut in tin, each figure being $2\frac{1}{2}$ inches long, and for painting the back ground, which is to be a disc, 6 inches diameter, stencil plates have also been provided.

Each overseer is to employ as many painters as he can manage and he will observe the following rules :—

The back-ground disc, for the numbers in each block, is to be the same colour as the block on the map.

The figures are to be red.

The overseer is to take a painter round a block commencing at a corner in a main street and is to keep to the right. Each square or collection of houses is to be gone through in this way until that block is finished. The painter must have only the one colour which belongs to that block, and the overseer must show the painter the whole block and must see that he has the proper colour. Having shown the painter his work, the overseer can leave him to paint, and show another painter over another block.

The numbers for each block should commence at 1 and be continued consecutively until the block is finished. In some districts there may be 200 or 300 houses in a block.

In case there is more than one entrance to a house, the second entrance is to be marked with a ×. In case of a godown or shop attached to a house and under the same roof, but with no entrance from inside, the godown or shop is to have a separate number.

If the end of a pial is covered in and has no entrance from within, it is to have a separate number; occupied godowns in European compounds are to have a separate number.

Each overseer will probably be able to manage four or five painters, as those who are painting discs one day will be numbering the next.

Each overseer will have one clerk, who will follow the painter and will ascertain (1) the number of houses in each block, (2) the number of people in each house approximately, (3) the most suitable place to sub-divide a block.

Old census numbers are to be scored out. The painters will be paid at the rate of 1 pie for each disc and 1 pie for each figure.

The work was commenced on the 1st of August 1890 and was finished on the 31st of October 1890.

As most of the blocks thus coloured on the map contained more than 60 houses, it was necessary to sub-divide them; a clerk on Rs. 15 a month was told off to each division to assist the overseer in dividing the blocks up to as to contain about 60 houses; care was taken to arrange that each new block commenced and ended at a corner of a street where it was possible.

A number was then given to each block and this was written on the map.

The division was then divided into circles, each circle containing about 10 blocks. The circles were then numbered and written on the map. There were 1,287 blocks and 113 circles.

The next operation was the preparation of a register of houses (see appendix A). Five forms were bound together in a book with a thick card board back so as to give support to the pages and enable the clerks to get through their writing quickly; one book was allotted to each block; on the first page of each of those books was written division, circle number, block number, house number to house number.

These building list books were distributed to the eight overseers to write on the cover of each book the names of the streets which formed the boundary of the block to which the book referred.

Seventy-two clerks and overseers in municipal employ and the eight clerks above referred to were then told off to prepare these lists, As. 12 being allowed to the municipal clerks for each book, and the subsequent work which it entailed. These men were afterwards appointed supervisors.

The chief points that required attention in preparing this list were—

(1) to enter the name of the head of each family,
(2) to note if the building is thatched, tiled or terraced,

(3) to note if any of the census numbers have been washed out, disfigured, or if any houses have been omitted or numbered twice. When the building lists were all finished (9th January 1891), a list showing the number of inhabited houses was made out, so that a more accurate estimate of the schedules required might be made.

It was originally intended that the clerks in the Government employ should assist in the preliminary as well as the final census, but this idea was afterwards abandoned and their services were only availed of for the final census.

In order to take the preliminary census, it was necessary to employ enumerators, and the supervisors selected 249 enumerators for the preliminary census. This was commenced on the 23rd January and was finished on the 14th February.

On the 14th February the overseers were given the abstracts and were told to prepare the circle list allotting to each Government clerk, whose services have been lent, the block nearest to the street in which he lived (see appendix B). When it happened that there were not sufficient clerks for the blocks of one division, they were drawn from a division that had a surplus. Having allotted one block to each of the Government clerks, it was found that 126 more were wanted for the first division for the final census. Each supervisor from among applicants selected eight or ten enumerators according to the additional number required for the blocks in his circle.

The next step was to instruct the enumerators in their duties at the final census, and for this purpose they were told to assemble at five separate places.

Each Government clerk was advised of the place he was to go by a notice which was filled up by the overseers and forwarded to the heads of departments in a covering letter; at the same time the clerk was asked to sign a receipt for As. 4 which was to be given him on the 25th February for providing a light.

The circle lists were printed between the 21st and 24th February, seven copies of each being struck off at a cost of Rs. 333–12–0. Several of the Government offices sent in alterations and substitutes at the last moment, which caused a good deal of inconvenience, as the substitutes did not always live in the same district as the original nominee.

Appendix C is a copy of the instructions given for the final census. Each charge superintendent and supervisor were also provided with the 'Manual of Instructions.'

The staff employed in the preliminary census consisted of—

8 charge superintendents,
8 assistant charge superintendents, viz., the overseers,
72 supervisors, and
249 paid enumerators.

The preliminary record was very carefully compiled.

In the final census the staff employed comprised—

8 charge superintendents,
8 assistant charge superintendents,
72 supervisors, and
1,465 enumerators, 418 of whom were paid, 974 were officials and 73 municipal employés.

The paid enumerators were drawn principally from clerks out of employ and students.

The system of employing Government clerks for final census was very satisfactory on the whole. There was practically no difficulty in these officials finding the houses in the block to which they were allotted. The system of numbering the houses assisted them greatly in this respect. In a few instances the numbers were obliterated, but these were readily traced from the numbers of the neighbouring doors. The numbering was finished four months before the final census, which gave ample time for obtaining the necessary information for the preliminary census, and it is not advisable that this period be restricted to any great extent on future occasions.

The following is a list of schedules used :—

184 books of 50.
636 do. 30.
836 do. 20.
235 do. 10.

Fifteen thousand and two hundred house-holders' schedules were issued from the office, but there is no record of the quantity used. Very few native house-holders' schedules were issued, and they might be dispensed with on a future occasion. It is strongly recommended that house-holders'

schedules be used in future for the preliminary census only and returned to the enumerators seven days before the final census, except in the cases of jails, hospitals, hotels and clubs. On the evening of the final census the house-holders' schedules can be corrected by the enumerators where any change had taken place.

The final census was commenced at 8 P.M. on the 26th February and nearly all the work was finished by midnight, though there were some exceptions. From personal observation of the work of enumerators during the night and from the reports of the charge superintendents, there is no doubt that the work was systematically and conscientiously performed.

In accordance with circular (appendix C), the supervisors assembled at the Census office at 4 P.M. on the 27th and re-assembled on the 28th February to complete the circle and charge abstract. These were finished at 5 P.M. on that day: the enumerators' books were left at the Census office and officially handed over on the 24th March.

Appendix D is an estimate of the census expenses, which was forwarded to the Superintendent of Census Operations on the 12th May 1890 and the actuals up to date.

Travellers by road were taken by the police at the toll-gates. Persons found sleeping under the trees were also enumerated by that agency. Within military limits the military authorities compiled the census returns. The census of Buckingham Canal was taken by the Executive Engineer. The census of jails, hospitals and hotels were taken by those in charge.

The definition of a house was laid down in circular No. $\frac{1}{22}$, dated Ootacamund, 28th April 1890. A house is a dwelling place of one or more families with their servants, having a separate principal entrance from the common way. In carrying out this definition, houses were numbered which were omitted on previous occasions; hence the increase in the number of houses is due to the definition more than to actual increase of dwellings. The increase in population too may be due in some measure to the system adopted in carrying out the census.

Appendix A.

Census, 1890–91.

Madras City. *Colour.*

Division No. *Block No.* *Circle No.*

Street.	Houses.		Name of principal occupant.	Remarks.	
	Serial number.	Descriptions. House, shop or temple.		House, terraced, tiled or thatched.	Other remarks.

APPENDIX B.

CENSUS, 1890–91.

Circle List.

Madras City. *Division No.*

Charge number.	Circle number.	Name and occupation of supervisor.	Division number.	Number of block.	Enumerators.		Number of enumerators' books for the block.	Number of houses.	Number of other buildings.	Total.	Remarks.
					Name.	Occupation or office.					

Appendix C.

To

The Charge Superintendent.

Sir,

Please arrange for the supervisors and enumerators of your charge to be present at
at 7 A.M. on the 25th instant.

All schedules should be arranged in order and tied up in circles. Please see that this is done and that they are taken to the above-named place in good time.

At 7 A.M. on the 25th, you will call up, circle by circle, the supervisors and enumerators of each circle of the
division.

To each supervisor should be given the circle list and the appointment orders for the enumerators of the circle.

To each enumerator should also be given As. 4 for a light for which a receipt should be obtained by you.

The supervisor and the paid enumerator should be instructed to go and show the new enumerators their blocks and the nature of their work.

The supervisor must name a place of meeting his enumerators on the 26th at 7 P.M., and must inform you and his enumerators of this in writing on the 25th morning.

The supervisor will muster the enumerators on the 26th at 7 P.M. at the place arranged and will distribute to each 1 bottle of red ink, 1 pen-holder and loose schedules and tickets for enumerating houseless poor found sleeping on pials and in verandahs.

The supervisor will, before that date, obtain from the office sufficient bottles, ink, pens, holders, 50 schedules and 200 tickets.

Enumerators should be instructed to call for house-holders' schedules at 7 A.M. on the 27th where they have been left.

Enumerators should be instructed to take on a spare schedule the census of houseless poor found sleeping in verandahs and on pials. No entry need be made as to number of house or street in which they are found. The schedules must be pinned with the house-holders' schedules to the book.

At 10 A.M. on the 27th, the supervisor should muster the enumerators at the place where they met the night before, and each enumerator should prepare an abstract.

After these have been checked, the unpaid enumerators may be dispensed with.

The supervisors must then prepare a circle abstract with the help of the paid enumerators.

When this is finished, the supervisor and paid enumerators should go at about 4 P.M. to the Census office in White's Road, where they will arrange themselves in groups according to their divisions.

You are requested to see that you have all the circle lists and sufficient money in 4-anna pieces for distribution.

You are requested to be at the Census office at 4 P.M. on the 27th.

In cases where one supervisor has two circles, the enumerators may be called up together, but a separate abstract must be prepared for each circle.

APPENDIX D.

Statement of Expenditure on Census Operations in 1890–91.

Head of account.	Amount of estimate.			Amount of expenditure.		
	RS.	A.	P.	RS.	A.	P.
House-numbering	3,000	0	0	2,228	5	10
Lights, red ink, &c.	500	0	0	444	0	0
Petty stationery, &c.	1,500	0	0	951	9	8
Remuneration for non-officials	8,500	0	0	6,279	3	11
Total ...	13,500	0	0	9,903	3	5

NOTE.—The area of Madras is 27·29 square miles.
The population according to census of 1891 is 452,518.
The number of houses, 60,103.

CHAPTER IV.

VACCINATION.

Historical sketch of small-pox epidemics.—The date usually assigned for the first appearance of small-pox is A.D. 568, when the disease broke out among the Abyssinian Christians, who were besieging the city of Mecca in Arabia. The ravages caused by the disease among the besiegers resulted in their sudden retreat from the city. Though the year A.D. 568 is universally admitted to have been the year in which small-pox can first be clearly recognised as the disease of the present day, yet it is probable that it has existed from the earliest times. Philo, an Alexandrian Jew, of the first century, in his book on the life of Moses, describes the plague of 'boils,' which was inflicted on the Egyptians as an eruption covering the whole body, and not confined to the glands like true oriental plague; in addition to the eruption being described as equally distributed over the whole body, the account of it given by Philo has another and still more characteristic resemblance to small-pox—"the eruptions are purulent pustules, assuming most generally a confluent character."

By the ancient Grecian and Roman historians there is frequent mention of a disease which bears a close resemblance to small-pox. Thucydides, in his history of the Peloponnesian war, describes an eruptive disease in which the skin was somewhat red and covered with small pustules and blotches, and the eyes inflamed and running with water. Heroditus describes a similar disease which prevailed about the same time in the army of Artaxerxes, and Livy records ten outbreaks of epidemics *common to men and cattle* between the years B.C. 464 and B.C. 178.

It would be impossible within the limits of this chapter to give instances of all the recorded epidemic outbreaks of disease bearing a strong resemblance to the small-pox of the present day, which have occurred both in Asia and on the continent of Europe during the last 1800 years; there is sufficient evidence to show that in numerous cases the disease was of a varioloid character, and that in some instances it was common to man and cattle.

Discovery of vaccination.—In the year 1775, Dr. Jenner, a physician practising in Berkely, Gloucestershire, noticed that milk maids who had suffered from a particular kind of sore on the hands, which they affirmed had been contracted by milking cows with similar sores on the teats enjoyed a complete immunity from small-pox, which was then very prevalent in the neighbourhood.

Identity of cow-pox with small-pox.—Further investigation on this subject convinced Dr. Jenner that, not only did those who had contracted sores from infected cows enjoy an immunity from small-pox, but that the actual inoculation of the small-pox virus failed to communicate the disease to them. On this observation he founded his theory that the disease common amongst cattle and known as cow-pox was identically the same disease as that which was known as small-pox in man.

Vaccine pustules the result of inoculation with matter from cow.—To test the correctness of this theory he inoculated the human subject with matter from the pustules on the teats of the cow, the result being that vaccine pustules appeared. Some months after the vaccine pustules had run their course, he inoculated those persons who had been the subject of them with small-pox virus; but in every case he failed to communicate the disease to those who had already been vaccinated.

By frequently repeated observations he convinced himself of the utility of vaccination from the sores on cow's teats as a preventive against small-pox. To complete the utility of his discovery, one thing more was wanting that the matter taken from a vaccine pustule would convey the same immunity as the virus from the cow: this he proved to be true by repeated observation.

Object of vaccination.—The object of vaccination is to protect the system from a harmful disease by introducing into it, through the medium of a specific virus, a disease vaccinia, in itself harmless, but which conveys immunity from small-pox to those who have been the subject of it.

Vaccinia may be described as an eruptive disease, the eruption not being general, but confined to the locality where the virus has been inserted.

Operation of vaccination.—The operation of vaccination consists in the introduction of vaccine lymph into the arm of a healthy subject. There are various methods of performing the operation, but the method adopted in each

case depends on the means which have been followed to preserve the vaccine matter. If the lymph has been collected in capillary tubes, which is the usual practice in this presidency, a number of minute superficial punctures are made at the part selected for the operation, which should be on the outside of the arm a few inches from the shoulder, at a point corresponding to the attachment to the bone of the arm of the large muscle which surrounds and gives shape to the joint, the end is broken off the hermetically-sealed capillary tube and the contents deposited on the superficial punctures.

Another method of performing the operation is to make a puncture with a sharp lancet charged with lymph, the lancet being introduced obliquely so as to make a valvular opening, the direction of which should be from above downwards so as to permit of the lymph readily entering; or the skin can be scratched with a lancet and the lymph rubbed in on the abraided surface.

It is not necessary for efficient vaccination that any blood should be drawn during the operation: the surface should simply appear reddened and be moistened by the exudation of a small quantity of serum.

Vaccination with stored lymph.—When vaccinating with stored lymph, caution is necessary, lest it may have become inert through long keeping. Pure vaccine in capillary tubes cannot be relied upon for more than a week in the plains, unless kept in an ice box. When prepared as glycerine paste, *i.e.*, thoroughly mixed with $1\frac{1}{2}$ times its weight of pure glycerine, and carefully stored in glass phials or Saigon tubes, it will retain its activity for a week or ten days, except in the hottest weather. The lanoline vaccine introduced by Surgeon-Major King (now Sanitary Commissioner of Madras) in 1890, is said to retain its activity for much longer periods. This preparation is a mixture of pure vaccine with anhydrous lanoline, the usual strength being 1 to 7. It can be relied upon up to 21 days. The best results, however, are undoubtedly obtained from direct calf-to-arm vaccination.

Arm-to-arm vaccination.—Arm-to-arm vaccination is preferable in many respects to vaccination with stored lymph, but great care should be taken in the selection of cases from which the lymph is procured. As a rule, it should never be taken from cases of re-vaccination, but always from fine healthy children, born of healthy parents who have no taint of syphilitic or other hereditary disease. The greatest possible care should invariably be exercised in taking vaccine

matter from the arm of an infant to secure the absence of any admixture of blood.*

Number of vesicles produced.—The greater the number of vaccine vesicles produced in any case, the more certain and complete is the immunity from small-pox which will be enjoyed by the person operated on. The following table from statistics of the London Small-pox Hospital shows the relationship :—

Cases of small-pox.	Number of deaths per cent.
Unvaccinated	35½
Vaccinated but no mark	21¾
One mark	7½
Two marks	4⅛
Three marks	1¾
Four or more	¾

Typical vaccine cicatrix.—In every case of vaccination there should be at least six inoculations, three on each arm, and the resulting cicatrixes should present the following appearances: circular in shape of a paler colour than the surrounding skin, the surface covered with little depressions or pits, radiated, and with a well-defined edge. *An indifferent cicatrix*, the result of inefficient vaccination, is indistinct with no well-defined edge, the surface is smooth without depressions or pits.

Vaccination in the city of Madras is chiefly carried out with matter taken from the heifer direct on the fifth day after inoculation. The vaccine matter is taken from the vesicles and either directly introduced into the subject to be vaccinated, or collected for future use in capillary tubes which should be hermetically sealed at both ends. This is unquestionably the best and most satisfactory method.

Age at which children should be vaccinated.—Vaccination ought to be performed when children are from two to four months' old; the limit fixed in Madras is six months, and persons failing to have their children vaccinated within that limit are liable to prosecution. It is most important that children who are to be vaccinated should be in a good state of health at the time; they should be free from skin affections and all acute diseases, such as diarrhœa. If small-pox is epidemic, or even prevalent, in the neighbourhood, vaccination should be performed at a much earlier date than

* In the Madras Presidency the use of the human lymph has been prohibited by G.O., No. 2128 L., dated 3rd September 1891, L. and M.

two months: it is better to perform the operation immediately after birth than to run the risk of contracting small-pox by delay.

Course and appearances of vaccine vesicle.—The operation itself is not of a formidable character and is rarely followed by any but the slightest constitutional disturbance. At the end of the second or beginning of the third day small papular elevations are visible over the points of inoculation with slight redness around; the elevation and redness gradually increase, and by the fifth or sixth day distinct vesicles form.. These vesicles are round or oval, bluish white, raised at the margin, and depressed at the centre. On the seventh day an inflamed areola forms round the vesicle, which continues to enlarge during the eighth day, when it is in its most perfect state, being full, tense, rounded, and much raised at the margin, and of a pearly white colour. The areola continues to enlarge for a couple of days, reaching a diameter of from one to three inches, accompanied with considerable induration and swelling. On the tenth day it begins to fade and at the same time the contents of the vesicle become opaque, while it gradually dries up and becomes brown in the centre. By the fifteenth day a reddish brown scab is formed, which darkens in colour, shrivels up, and finally falls off on the twenty-first or twenty-second day.

In young children there is generally some slight constitutional disturbance after vaccination, the child becomes restless and fretful and suffers from diarrhœa: these symptoms do not always come on at once, but generally about the ninth day, when the vesicle is changing in appearance and becoming clouded; at this time the temperature often goes up, and in some cases reaches as high as 103° Fah.

Re-vaccination.—As the protective influence of vaccination wears away with the lapse of time, it is now generally recommended that re-vaccination should be performed about the age of 12 years. The operation differs in no way from that of primary vaccination, but the course, in successful cases, is generally more rapid, and the constitutional symptoms more severe, probably owing to the age of the patient and the greater difficulty of preserving the vesicles from injury both during and after maturation.

Protective influence of vaccination.—There can be no doubt that vaccination, when satisfactorily performed, is a preventive against small-pox, by it small-pox has practically disappeared from England where strict compulsory vaccination laws are in operation; and here in India, where great prejudices against it exist both on religious grounds and from

distrust in it, wherever it has been possible to carry out vaccination efficiently the immunity from small-pox has been most marked. In native regiments, where every sepoy is vaccinated after enlistment and where every infant born in the lines is vaccinated, small-pox outbreaks are almost unknown.

During the very severe epidemic which occurred in Madras in the year 1884, the mortality from the disease amongst the men, women, and children of the regiments then stationed at Perambur and Ráyapuram was only ·45 per 1,000 as compared with a mortality of 10·1 per 1,000 amongst the civil population.

To be protective vesicles should present certain definite appearances.—Vaccination to be surely protective against small-pox must be properly performed and the resulting vesicle must run a certain course and present certain definite appearances. These have been described already. When these appearances of the vesicle have been manifested after vaccination, it may be pretty confidently asserted that the operation has been successful. Great care, however, should be taken to see that these conditions are fulfilled, and that no case of vaccination is returned as successful which is not so really.

Dangers of inefficient vaccination.—When children or adults, who are supposed to have been protected by vaccination, but who have really never been so, catch the disease and possibly die from it, distrust in vaccination as a preventive against small-pox is sure to arise amongst the immediate friends and relatives of the person attacked, and in this way one single case of inefficient vaccination may be the means of propagating opposition to, and prejudice against, it far and wide.

Method of collecting lymph.—The best method of carrying on vaccination is by using lymph direct from the calf, or, failing this, from the arm of a healthy infant; but if it is necessary to collect and store the lymph in capillary tubes, the following plan should be adopted. The vesicle selected should be carefully ruptured, care being taken that no blood becomes mixed with the contents, and when sufficient lymph has exuded, one end of the capillary tube should be inserted into it until a sufficient quantity has risen to fill one-half of it. When charged, the tubes should be hermetically sealed by melting the ends in the flame of a candle; the contents of the tube must be kept away from the flame as much as possible, as the effect of heat on lymph is to render it opaque, and in this condition its protective influence is

impaired. The ends of the tubes can be closed by inserting them in melted sealing wax.

Arguments against vaccination.—Some people deny the efficacy of vaccination as a preventive against small-pox, and some go further and assert that it is positively hurtful: they say that by it hereditary or acquired constitutional disease has been propagated and that from it, in some cases, the very disease, which it was adopted to prevent has resulted. It is necessary, therefore, to say a few words in refutation of the views of the "anti-vaccination" party.

Arguments in favour of vaccination.—Before the introduction of vaccination the annual small-pox mortality in England was at the rate of 3,000 per million of population, with the present population this would amount to 126,000 per annum. In the year 1871, vaccination had for many years been recognized by the vast majority of people who were capable of forming an opinion on the subject as an undoubted preventive against small-pox; but the Compulsory Vaccination Act did not then exist, and individuals were not compelled by law to have either themselves or their children vaccinated.

In 1871 there was a severe epidemic of small-pox in the United Kingdom. Dr. Farr, Registrar-General of England, writing of this epidemic, says: "The year 1871 is memorable for an epidemic of small-pox which ravaged several parts of the kingdom in a way of which there has been no example since the year 1838, when the deaths by small-pox were 16,268.

"In the 24 consecutive years that ended in 1871 the annual deaths by this disease ranged from 1,320 to 7,684 in 1864, the latter number they never exceeded till 1871 when the deaths ran up to 23,126." Assuming the population of the United Kingdom to have been 36,000,000 in 1871, this gives a mortality from small-pox during that year at 642 per million of population compared with the 3,000 ordinary annual death-rate before vaccination was introduced. It must be remembered that 1871 was an exceptional year. Excluding epidemic influence the ratio of deaths per million of population would, of course, be much smaller; but 1871 has been purposely quoted in order to prove that the death-rate in a year of an exceptionally severe outbreak of disease since the introduction of vaccination, but before it was made compulsory, compares most favourably with the annual average mortality before vaccination was introduced.

Effect of vaccination on mortality of those attacked.—Vaccination has had a beneficial effect not only in reducing the number of cases of small-pox, but it has considerably diminished the mortality of those attacked, the mortality amongst the unvaccinated being much greater than amongst those who have been protected by vaccination, as is clearly shown from the following table taken from the Cork Street Hospital report on small-pox :—

Hospitals.	Mortality per cent.		
	Vaccinated.	Unvaccinated.	General.
Cork street	10·8	71·8	21·6
Hardwicke	11·2	78·57	20·0
Cork	5·5	58·0	22·5
London small-pox	14·9	66·2	18·8
Hampstead	11·4	51·2	19·36
Homerton	5·9	37·7	16·3

The mortality from the disease is thus shown to have varied amongst those who had been vaccinated from 5·5 per cent. in the Cork Hospital to 14·9 in the London Small-pox Hospital, and amongst the unvaccinated from 37·7 in the Homerton Hospital to 78·5 in the Hardwicke Hospital.

During an epidemic in Oldham in 1893, the percentages of deaths were 3·6 among the vaccinated and 27·6 amongst the unvaccinated. In another in Birmingham in 1894 among the vaccinated 4·4 and unvaccinated 33·5.

These figures should convince the most sceptical of the advantages of vaccination as a preventive against small-pox. They are capable of but one explanation, namely, that those people whose systems had been previously subjected to the influence of the vaccine disease presented a less favourable resting place for the small-pox contagion when brought in contact with it than those who had not been vaccinated.

Effect of vaccination on the type of the disease.—In addition to diminishing the number of persons attacked by small-pox and lowering the mortality of those attacked, vaccination appears to exert another and very important influence, that of altering the type of the disease. There are three important varieties of small-pox :—

(*a*) *Discrete.*—The most mild variety ; in it the pocks are distinct and do not run into each other though they may touch.

(*b*) *Confluent.*—A much severer type in which the eruption is very abundant and the pocks run into each other.

(*c*) *Malignant.*—The most dangerous variety, almost invariably fatal amongst the unvaccinated.

Experience teaches that by far the greatest number of cases of small-pox which occurs among those who have been vaccinated is of the discrete variety, and that next in order of frequency comes confluent, while cases of a malignant character are very rare, and when they do occur may be safely attributed to some constitutional peculiarity. The following table is instructive and gives support to the opinion that the type of the disease is modified by efficient vaccination. It is taken from the Cork Street Hospital report :—

—	Discrete.			Confluent.			Malignant.			Total.		
	Total.	Died.	Per cent. mortality.	Total.	Died.	Per cent. mortality.	Total.	Died.	Per cent. mortality.	Total.	Died.	Per cent. mortality.
Vaccinated...	443	1	0·2	143	46	32·2	25	18	72·0	611	65	10·8
Unvaccinated	17	6	35·1	94	67	71·2	24	24	100·0	135	97	71·8
Total ...	460	7	35·3	237	113	47·6	49	42	85·7	746	162	21·6
Per cent. vaccinated in each class.	96·3			60·4			51·9			81·8		

The mortality amongst the vaccinated in the discrete variety was practically nothing, but amongst the unvaccinated in this class, 35·1 per cent died. In the confluent variety the deaths amongst the unvaccinated was 71·2 per cent., while amongst the vaccinated, it was only 32·2 per cent., almost the same as the percentage of mortality among the unvaccinated in the discrete variety. The mortality amongst the unvaccinated in the malignant variety was 100 per cent., amongst the vaccinated 72·0, or practically the same as the mortality among the unvaccinated in the confluent variety. The effect of vaccination appears to have been, in the cases recorded in the above table, to reduce the mortality of confluent cases to that of discrete unvaccinated, and that of malignant to the mortality of confluent unvaccinated cases.

The object aimed at in the foregoing remarks, has been to prove that the arguments in favour of vaccination as a preventive against and modifier of small-pox are very strong, provided the operation has been properly performed and good lymph employed. Since the introduction of compulsory vaccination in Madras in 1884, the deaths from small-pox have shown an enormous falling off as the following table shows :—

Years.	Deaths.	Years.	Deaths.
1875 ..	196	1885–6 ..	16
1876 ..	409	1886–7 ..	1
1877 ..	*	1887 ..	13
1878 ..	447	1888 ..	36
1879 ..	910	1889 ..	45
1880 ..	869	1890 ..	78
1881 ..	1,654	1891 ..	66
1882 ..	355	1892 ..	27
1883 ..	1,957	1893 ..	20
1884–5 ..	927	1894 ..	12

A community can only be considered as efficiently protected from small-pox when the number of cases of successful vaccination approximate very closely with the birth-rate.

Madras Bye-laws.—The bye-laws at present in force for carrying out compulsory vaccination in Madras are as follows :—

1. In these bye-laws :

Parent means the father or mother of a legitimate child and the mother of an illegitimate child.

Guardian means any person to whom the care, nurture or custody of any child falls by law or by natural right or recognized usage, or who has accepted or assumed the care, nurture or custody of any child, or to whom the care or custody of any child has been entrusted by any lawful authority.

Qualified medical practitioner means a person holding a diploma which entitles him to practise as a Surgeon or Physician in the Queen's dominions and also Honorary, Assistant, Native, and Sub-Assistant Surgeons, Licentiates of Medicine, Apothecaries and Hospital Assistants.

Vaccinator includes qualified medical practitioners, vaccinators employed by the Municipal Commissioners, and persons who hold the written permission of the President to vaccinate within the city.

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* Omitted as extraordinary.

Child means a boy under twelve years of age or a girl under ten years of age.

Protected child means a child that has had small-pox, or is certified to have been successfully vaccinated, or is certified to be insusceptible of vaccination.

Unprotected child means a child that has not had small-pox and is not certified to have been successfully vaccinated, or to be insusceptible of vaccination.

Depôt means a place or building where, by direction of the Municipal Commissioners, public gratuitous vaccination is performed.

2. If the President is satisfied that any person is competent to vaccinate, the President may grant to such person permission in writing to vaccinate within the city. The President may at his discretion revoke such permission.

3. If any unprotected child or the parent or guardian of such child is a female who, according to the customs of the country, does not appear in public, the President or Health Officer, or any person authorized by the President in that behalf, shall direct a female vaccinator to visit the house of such parent or guardian and there deal with the child as if it had been brought to a depôt and submitted for vaccination.

4. A vaccinator is competent to grant a certificate that a child is in a state unfit for vaccination, but such certificate shall be valid only for a period of three months from the date thereof.

5. If any parent or guardian, in cases which do not fall under bye-law 3, is desirous that a child should be vaccinated in his house, he may send an application to the President or Health Officer accompanied by a fee of eight annas for the vaccinator. If more than one child is to be presented for vaccination in the house, it should be so stated in the application, and an additional fee of two annas must be paid for each child after the first child to be vaccinated. If tube lymph is desired, four annas for each child to be vaccinated must be paid. If arm-to-arm vaccination is desired, a fee of eight annas and four annas for every mile of distance travelled by the subject must be paid. On receipt of such application with the prescribed fees, the President shall send a vaccinator to the house.

6. A vaccinator who has vaccinated a child and who has satisfied himself that the vaccination is successful, shall give to the parent or guardian of the child a certificate that the child has been successfully vaccinated.

7. If a vaccinator is of opinion that a child, which has been three times unsuccessfully vaccinated, is insusceptible of vaccination, he shall give to the parent or guardian of the child a certificate to that effect.

8. The parent or guardian of any unprotected child which is more than six months old, and which has resided within the city

for two months shall obtain the vaccination of the child under bye-law 5, or shall take the child to a depôt and submit it for vaccination, unless the parent or guardian holds a valid certificate that the child is in a state unfit for vaccination, or unless the case falls under bye-law 3.

9. When a child is brought to the depôt for vaccination, the vaccinator shall, if he finds that the child is in a state unfit for vaccination, deliver to the parent or guardian a certificate to that effect. When the certificate is no longer valid, the parent or guardian shall again take the child to the depôt and submit it for vaccination, unless he shall have in the mean time obtained a certificate under bye-law 5 or 6.

10. When a child is brought to the depôt for vaccination, the vaccinator shall, if he finds the child to be in a state fit to undergo vaccination, vaccinate the child and deliver to its parent or guardian a memorandum stating the date on which the vaccination has been performed and the date on which the child is to be inspected in order to ascertain the result of the operation.

11. When a child has been vaccinated under the last preceding bye-law, a vaccinator from the depôt shall, on or after the date of inspection stated in the memorandum, proceed to the house of the parent or guardian. The parent or guardian of the child shall produce the child for inspection when required to do so under this bye-law by a vaccinator between the hours of six of the clock before noon and six of the clock after noon. The vaccinator shall inspect the child, and, if the vaccinator is of opinion that the vaccination has been successful, he shall give to the parent or guardian of the child a certificate to that effect. If the vaccinator is of opinion that the vaccination has been unsuccessful, the parent or guardian shall obtain a certificate under bye-law 5 or 7, or shall again take the child to the depôt and submit it for vaccination.

12. The President may cancel any certificate given under these bye-laws if it be proved to his satisfaction that such certificate has been improperly given or obtained, and thereupon such certificate shall no longer be valid.

13. Every parent or guardian who procures the vaccination of any child by a private practitioner or other authorized vaccinator shall forward the certificate of successful vaccination to the President or Health Officer within twenty-one days from the date on which it is granted.

14. The President or Health Officer or any person authorized by the President in that behalf, if he has reason to belive that there is an unprotected child in any house, may call upon any occupant of the house or any parent or guardian of any child in the house there to produce for inspection the children under his care and to state the age, parentage, and place of birth and registration of each child so far as is known to him.

Any occupant, parent, or guardian, so called upon, who, without reasonable excuse, refuses to produce for inspection any child in his care, or to state the age, parentage, and place of birth and registration of any child in his care, shall be liable, on conviction before a Magistrate, to a fine not exceeding twenty rupees.

15. No fee shall be charged by a vaccinator at a depôt or by a vaccinator inspecting a child under bye-law 11 or by a female vaccinator sent to a house under bye-law 3 for vaccinating a child or for granting a certificate.

16. A vaccinator who, by a careless operation or by the use of lymph which he has reason to believe is impure, injures the health of a child :

A vaccinator who refuses to give a certificate as required by bye-laws 6 and 7 :

A parent or guardian who refuses to submit a child for vaccination or for inspection after vaccination to a female vaccinator sent to the house under bye-law 3 :

A parent or guardian of an unprotected child who omits to obtain the vaccination of the child under bye-law 5 or to take it to a depôt and submit it for vaccination as directed by bye-law 8 :

A parent or guardian who omits to again take a child to the depôt and submit it for vaccination as directed in bye-law 9 :

A parent or guardian who omits to produce a child for inspection as directed in bye-law 11 :

A parent or guardian who omits to forward a certificate as required by bye-law 13 :

shall be liable, on conviction before a Magistrate, to a fine not exceeding twenty rupees.

17. A parent or guardian, who, after conviction under bye-law 16, continues for one month his refusal or omission, may again be convicted before a Magistrate and shall again be liable to a fine not exceeding twenty rupees.

CHAPTER V.

ROADS, AVENUES AND STREET LIGHTING.

(1) ROADS.

Materials used in construction.—In India, metalled roads are ordinarily constructed of granite (so called), trap, laterite, or broken brick.

Roads should be raised above natural surface.—In forming new roads the formation level, that is the surface of the embankment before it is metalled, ought to be raised well above the surrounding ground, and sufficient waterways and culverts must be provided to allow any cross drainage to follow its natural course. Side ditches should be formed to catch the water flowing from the road ; these should be graded towards the natural cross channels. If the sub-soil be wet or spongy, it must be brought into a hard condition. All embankments ought to be rolled or well dumped with heavy beetles.

Telford's and MacAdam's methods of forming road surfaces.—The proper manner of metalling a road is a matter of some diversity of opinion for, according to MacAdam (from whose name is derived "*macadamising*"), all that is required is a proper formation of the bank on which the broken metal can be laid to a depth of 6 to 10 inches, while Telford advocated the laying of large boulders as a foundation for the metal. Neither of these Engineers used any binding material in forming their roads ; but in India the use of binding material is universal. The necessity for this is due to the irregularity of the rainfall, for, whereas in England, the rain falls more or less throughout the year, here in India intervals of from three to six months without any rainfall, are constantly experienced, so that if some binding material were not used the roads would get rapidly dry and break up.

Amount of binding material dependent on rainfall.—The amount of binding material necessary for a road depends, to some extent, on the distribution of the rainfall throughout the year, more material being used where there

are long periods without rain than in those places where the fall is more frequent. The proper proportion of binding material is one that is not easily fixed; if there is a large proportion there may be a good road in the dry season which will be extremely muddy and soft in the wet season; on the other hand, if too little binding material is used the road may break up in dry weather, though a sufficient quantity of rain may render it an admirable road.

Quality and size of metal. — Macadamised roads (which description now includes all broken stone roads, whether mixed with gravel or not) should be formed, according to MacAdam, of hard, tough and durable granite whinstone trap rock or compact limestone; the stones should be broken until they roughly approximate to a cubical shape not exceeding six ounces in weight, which, on an average, will give a cubical stone 1·6 inches in length on each angle.

Stone-breaking machines.—Blake's stone-breaking machine with the expenditure of one-horse power for each cubic yard per hour, will break stones into cubes $1\frac{1}{2}$ inches in length on each side.

Conditions laid down for supply of metal in Madras.—It is usual to require that the stone be broken, so that it shall pass through a screen having meshes of one and one-half inches, and that not more than 20 per cent. of the stone shall pass through a screen with meshes of three-fourths of an inch. The amount of binding material, *i.e.*, gravel used with granite for roads is from one-third to one-fourth the quantity of granite.

Thickness of metal to be laid on at one time.—No road ought to be laid down in layers of a greater thickness than four inches at one time. This thickness ought always to be consolidated by beating, ramming or rolling, before an additional layer is put on.

Method of effecting repairs.—A road ought to be thoroughly repaired by loosening the surface all over with a crowbar or pick and then spreading uniformly over it the first layer of metal.

Side slopes of roads.—The side slope of the surface of the roads ought to vary with the rainfall; if the roads will be subjected to exceedingly heavy concentrated falls, that is a very large quantity of rain in a short period, the side slopes of the road ought not to be so great as in places where the fall of rain is less in quantity during an equal period of time, otherwise the roads would be cut up into ruts.

Width of roads.—The subject of width and cross section of a road is of importance ; as regards the first, a wide road is best. It is an error to suppose that the cost of repairing a road depends entirely on its extent of surface and increases in the ratio of its width. The cost depends mostly on the nature and extent of the traffic, though, of course, for a wide road the first cost is greater.

A Slope found suitable in Madras.—The form of cross section to be given to a road is a matter of still greater importance. Some persons advocate considerable curvature in the upper surface, while others object to that form. One of the best forms of a road is that in which the road slopes up to the centre, the slopes being united at the centre with radius of 90 feet or above. The side slopes vary from 1 in 30 to 1 in 50. A slope of 1 in 50 has been found the best slope in Madras, the proper slope is a matter of experience.

Stone tests.—In order to test the fitness of any stone for use as road-metal, the best way is to lay it down on a certain length of roadway ; but when selecting a stone for trial it is also well to place it under the following tests :—

(1) Make a trial of the stone for toughness which is best done by ascertaining how much can be broken by the usual labour in a fixed time ; compare this with the time required for other stone in use.

(2) Ascertain the power the stone has to resist abrasion : this may be done by holding the stone against a grindstone.

(3) Ascertain also the power required to crush cubes of the stone of the size to be used in the road.

(4) The effects of the weather on the stone should also be noticed, and this may be ascertained by examining stone which has for time been subject to atmospheric influences.

Good road-metal must be hard, tough and not easily decomposed by the action of the weather.

Laterite roads.—Laterite roads should be formed on somewhat similar principles, except as regards the size of the stone used. The ordinary rule is that the average size shall not be larger than what will pass through screens having three-inch meshes ; this would allow of stones four inches on their longest angle being used. The larger pieces of laterite should be placed at the bottom and the smaller in the interstices and above. There is also a quantity of gravel used ; the proper quantity should be determined from the character of the laterite used, some classes of laterite being much harder

and less friable than others, which are easily broken and contain a good deal of clay.

Size of laterite used not very important.—The size of the laterite is not of very much importance, because if a laterite road be dug up and examined a short time after it has been laid down, it will be found that a solid cake of laterite, something like concrete, has been formed, and that portions of the road removed will come away in large cakes and not in nodular masses as laid down. Sand makes an admirable finish to a laterite road, but should not be put on thicker than one-fourth to one-half of an inch and before the road has thoroughly dried.

Laterite roads comparatively inexpensive to form, expensive to maintain.—The perfection of the surface of a laterite road, which is due to its really being a conglomerate crust, is no doubt a great recommendation, but as its strength depends on its retaining a certain amount of moisture, it is not suitable for heavy traffic, and rapidly breaks up in periods of long draught. It is therefore a road, comparatively inexpensive to lay down, but a costly one to maintain.

Darning roads.—"Darning" roads, that is, repairing the small holes and inequalities which appear here and there, is a bad practice, but a necessity in India especially in regard to laterite roads. There is nothing more difficult than to get coolies to "darn" well and neatly.

The following rules have been laid down in the city of Madras in regard to such repairs (as apart from reforms when the whole road is broken up and covered with new material) :—

(1) The portion of the road to be repaired is to be cut out in a square or an oblong, with straight sides and square corners.

(2) One darn is not to be put nearer than 6 feet to another darn ; if two repairs are required so near one another they must be made into one large repair.

(3) The place to be repaired is to be cut to a depth of not less than 3 inches below the level of the road surface.

(4) The material must be carefully packed in with gravel and enough water (but not so much as to make it into a puddle) and then rammed down thoroughly.

(5) The top of the darn, when finished, must be level with the surface of the road ; it must not be above, and it must not be below the original surface ; one plan is as bad as the other.

(6) When a large darn has been made, the place must be lighted by a lamp at nights.

(7) Each day the repairs done the day before must be examined and rammed and beaten again, if necessary.

Square "darns" last longer than oval "darns."—It may be noticed that the rules are, perhaps, not quite in accordance with the practice elsewhere, as for instance, that the patches ought to be square. It is found, however, that the results are much better than if the coolies are allowed to dig out the road to any shape resembling the original hole or depression (usually oval), and that, where the edges of the "darn" are at right angles to the line of traffic (only one cart in a hundred will pass exactly over the longitudinal joint), the "darns" form less inconvenience and last longer.

Metal ought not to vary in thickness.—After the metal has been evenly spread on a road, it ought to be of the same thickness from one side to the other and not thicker at the centre than at the sides over which portion the heavy traffic passes; it ought to be well rammed.

Ramming.—Ramming should be done by heavy wooden or iron rammers (about 50 lb. weight). The men ramming ought to advance in a line with each other, but they ought not to keep time.

Rolling.—When a road has been thoroughly rammed, rollers ought then to be brought into requisition. The importance of thoroughly rolling roads after extensive repairs is now thoroughly appreciated and a considerable expense is saved eventually by systematic rolling. The rollers may be stone or iron, and driven by manual, bullock, horse, or steam-power. The road should be perfectly watered before rolling, but not so as to make it too soft, or the material will rise up in waves before the roller.

Stone Rollers.—Stone rollers, about $4\frac{1}{2}$ feet in diameter and 5 feet long, require twenty bullocks to work them all day long, but a less number suffices when the road surface has become somewhat consolidated. The weight of such a roller is about six tons and gives 224 lb. per inch of bearing surface.

Iron Rollers.—Iron rollers are usually hollow cast-iron or wrought-iron cylinders. The former can be loaded by iron, or stone, up to any weight, the extra weight required being added above the framing. Wrought-iron rollers are closed cylinders and can be filled up with water from one end. These rollers are preferable to cast-iron, firstly, because of

their freedom from breakages, and, secondly, because of the easy method by which their weight may be increased.

Steam Rollers.—Steam rollers are, however, the best means for the consolidation of a road; these are somewhat in the form of a locomotive engine, the front roller under the smoke box is about 4 feet long, and covers that portion of the road between the two rear rollers which are each about one foot in length. These rollers weigh $7\frac{1}{2}$, 10, 15 or 20 tons, and as they have a total bearing surface of about 6 feet, give a pressure of, respectively, $\frac{7\frac{1}{2}}{6\times12}$, $\frac{10}{6\times12}$, $\frac{15}{6\times12}$, $\frac{20}{6\times12}$ tons or 233, 311, 466, 622 lb., respectively, to the lineal inch of bearing.

Pressure necessary to be exerted by Rollers.—The weight which is necessary to properly roll a road, depends (1) on the heaviest weights carried by a cart wheel, (2) on the breadth of that wheel, and the weight of a roller ought not to be less than that which will give the same pressure per inch as does the cart wheel. Thus, suppose that a cart, as a maximum, carries one-half of a ton, then the weight on each wheel would in pounds be $\frac{1\times2,240}{2\times2}=$ 560 lb., and if the wheel be 2 inches broad a pressure of 280 lb. to the lineal inch would be the result. Rollers giving less than this pressure would not in such case be very effective. Another fact must also be noticed, which is, that the larger the diameter of the roller the greater its bearing surface, the pressure which is exerted on the road is therefore not in exact proportion to the weight as has been supposed.

From a large number of replies elicited from the Engineers of various towns in England, it has been found that a ten-ton Aveling and Porter's Roller is the one which has most to recommend it. All authorities in England agree as to the great advantage in steam rolling and these may be summed up as follows:—

(1) Economy.
(2) Facilities of perfect construction and reform.
(3) Less inconvenience to the public.
(4) Comfort to persons using the roadways.
(5) Great consolidating power.
(6) Possibility of making roads at all times of the year.

It is said that the saving effected by steam rolling over a roller drawn by horses is 30 per cent.

The cost of rolling varies with the cost of fuel and labour employed.

In England the cost including flag men and driver varies from £0–15–6 to £2–10–0 per day : the average is about £1.

In Madras, Bombay and Calcutta the rates, respectively, are Rs. 21–9–0, Rs. 40–12–6 and Rs. 30–15–0 per 1,000 square yards.

The area which a steam roller can consolidate per day differs considerably in one town from another. In England the returns were (10-ton rollers) :—

Birmingham	1,000	square yards per diem.
Bournemouth	1,000 to 2,000	sq. yds. per diem.
Brighton	1,600	do.
Bristol	600 to 700	do.
Hull	700 to 1,400	do.
Leeds	1,500 (in summer)	do.
Portsmouth	900	do.
London (Marylebone) ..	750	do.

The average is probably about 1,000 to 1,200 square yards per diem. Madras, Bombay and Calcutta, respectively, return 835, 2,327, and 652 square yards as rolled daily, the number of rollers being 2, 20 and 4 respectively.*

During the operation of rolling, it is necessary to apply sand or gravel to the surface of the road after the lower layers have become somewhat consolidated. The stuff should not be applied earlier and about 3 yards in 100 square yards equal to about 1 inch in thickness is required. This penetrates only the upper interstices and makes it into a sort of cake. The materials require to be watered during rolling.

The cost of material for roads, of laying it down and of the general maintenance of roads varies considerably. The cost of the material is dependent on its hardness, its depth below ground, its geological character, the distance it has to be carted to the road, and the cost of labour; the laying of it down is dependent on the last item alone, if the material, as it ought to have been, has been properly broken and sorted before delivery.

"Ford's Notes" on roads.—The following paragraphs regarding road maintenance are extracted from 'Ford's Notes' on Building and Road-making, a most useful work, but one now unfortunately out of print, the last edition having been issued some eighteen years ago. The system explained has, no doubt, been altered since these 'Notes' were written,

* This is the total squares rolled per annum divided by the number of rollers and by 365.

especially on the roads to which he refers, and which are now in the hands of the Local Fund Boards. It is thought better to extract the matter fully, leaving the notes as they came from the writer's hand. They may be useful in enabling a comparison to be made with existing system :—

"Unless the requisite funds are allowed for the maintenance of roads it is wise to leave them alone, for money expended in forming them, if they are afterwards to be neglected, is only thrown away: 'keeping up a road' is a very different thing from 'repairing a road,' though the two are often confounded. Due attention to the former will greatly lessen the necessity for the latter. The former keeps the road always in good condition, the latter makes it so only occasionally, after intervals of various length, during which it is continually deteriorating in a geometrical ratio, so that the better the state in which a road is kept, the less are the injuries to it, and, therefore, the less is the expense of keeping it in this condition. The best time for making repairs to a road is the beginning of the monsoon, but on roads on which there is much traffic, it will not do to defer all repairs to that period, for not only would the traffic be much impeded, but the cost of the repairs would be much increased.

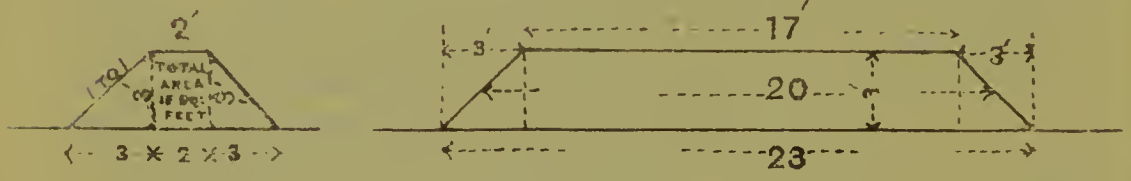
"To 'keep up a road' an establishment will be required, consisting of some carefully-trained head labourers with conico-pillaies or measurers and accountants and European overseers as paymasters and general superintendents. In the dry weather, carts and coolies will be employed under the measurers, preparing and conveying the material for the repair of the road, and in rainy weather the same parties will be engaged in reparing the road, turfing the side slopes, looking after the avenues, keeping the side drains clear and filling up all holes in the surface as soon as they are formed. A road suffers little from a heavy load drawn upon it, provided the surface is smooth and regular; but when ruts or holes occur, the wheel sinks into them with all the increased momentum of the fall and produces an effect that may be compared to that of a very heavy hammer falling upon the spot; and thus the hardest materials soon crush, and are ground to dust, while no such effect occurs on the road, while kept with a smooth and even surface. It is the duty of the establishment to see that all rules made for the preservation of the road are observed; that no encroachments are made on the road limits; that carts keep to their proper sides; and that all work is done in accordance with the general rules of the department.

"From 50 to 100 rupees a mile will be required annually for the repair of a road on which the traffic does not exceed 50 carts a day. After that number is passed, it has been found that one cubic yard of broken stone per mile is required annually for each cart that passes over such mile daily."

Metal should be stacked to a gauge.—The metal to be used for repairing roads ought to be stacked in uniform

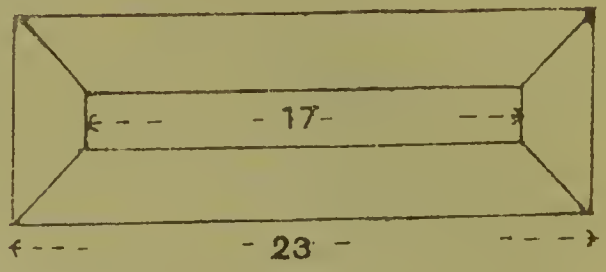
continuous stacks, and it is well to have gauges adapted for this purpose. The gauge for the broader roads and roads which are to be repaired with a greater thickness of metal must include a greater area than those for roads of less width and thickness of metal.

Measurement of materials.—For instance, take a road 20 feet wide which is to be relaid with 6 inches of metal ; then for each foot of road 10 cubic feet of metal are required. Now if the heaps can be continuous, heaps having a sectional area of 10 square feet would be sufficient, but, as the heaps can seldom be put down continuously, allowances must be made for passages through the heaps. In towns not less than 50 per cent. additional sectional area may be required, and taking this basis the heaps should be 15 square feet in area which may be packed thus :—



Thus a heap about 20 feet long will be sufficient for 30 feet of road, $\frac{L. \times B. \times H.}{20 \times 5 \times 3} = 300$; this would give a passage of 7 feet wide at every 23 feet.

Such a mode of measurement is however not exactly correct, and the proper measurement of such a heap is thus :—



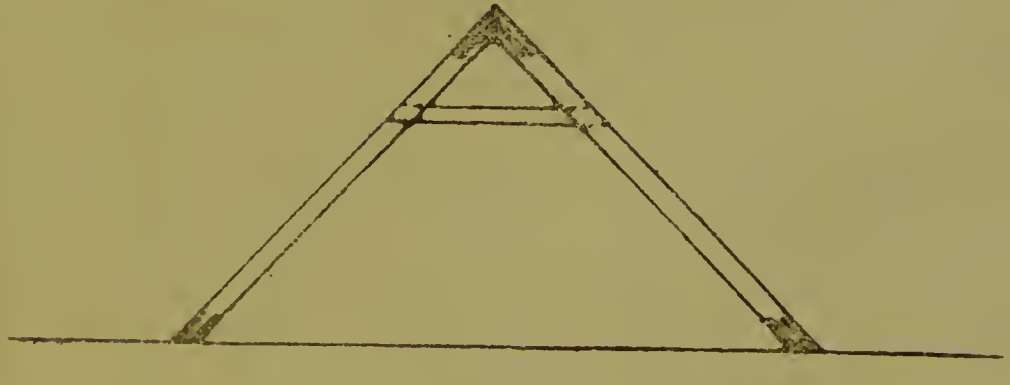
		FT.
Centre portion	$17 \times 2 \times 3$	= 102
Sides	$2 \times 17 \times 3 \times 1\frac{1}{2}$	= 153
Ends	$2 \times 2 \times 3 \times 1\frac{1}{2}$	= 18
Corners	$4 \times 3 \times 3 \times 3 \times \frac{1}{3}$	= 36
		309

When measuring on the former plan where the slopes are at an angle of 45°, a quantity represented by $\frac{H^3}{3}$ has to be added for each heap, and a similar constant quantity may be found for heaps with slopes at any other angle.

If a road is to be 10 feet broad or of the former breadth but with half the thickness of metal, heaps having a sectional area equal to one-half of those above referred to will suffice.

Adoption of standard gauges advisable. — The authorities in each town should fix the dimensions of the gauges to be used for each breadth and thickness of metalling combined, and gauges ought then to be prepared in accordance with those dimensions. There are great advantages in the use of standard gauges; they render the process of measurement easy, the materials will be uniformly deposited, the protection against fraud in regard to the amount of material delivered is considerable, as the amount deposited can be roughly checked by merely "stepping" the lengths of the heaps; lastly, the inconvenience to the public is, as far as possible, minimised.

Gauges for the size of heap referred to may be of teak of the accompanying form clamped at the angles with iron and bound with brass :—



The following table shows the amount, and average cost of material (granite or laterite) delivered and labour used, in Madras, for each square of road of the various thicknesses :—

Amount of material per square with various depths of metal and cost per 100 cubic feet.

——	6 inches.	5 inches.	4 inches.	3 inches.	2 inches.	Rate per 100 cubic feet.
	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	RS. A. P.
Granite ...	50	41⅔	33⅓	25	16⅔	7 8 10
Gravel ...	17	14	11	8½	5½	5 2 10
Laterite ...	50	41⅔	33⅓	25	16½	7 0 10
Gravel ...	15	12½	10	7½	5	5 1 5

Cost of material and labour per square.

Thickness in inches.	Granite roads.			Laterite roads.		
	Cost of granite per square.	Cost of gravel per square.	Labour per square.	Total cost per square.	Cost of laterite per square.	Cost of gravel per square.	Labour per square.	Total cost per square.
	RS. A. P.	RS. A. P.	RS. A. P.	RS. A. P.	RS. A. P.	RS. A. P.	RS. A. P.	RS. A. P.
6	3 12 5	0 14 1	0 6 2	5 0 8	3 8 5	0 12 3	0 6 0	4 10 8
5	3 2 4	0 11 7	0 5 2	4 3 1	2 14 8	0 10 2	0 5 1	3 13 11
4	2 8 3	0 9 1	0 4 3	3 5 7	2 5 7	0 8 2	0 4 2	3 1 11
3	1 14 3	0 7 0	0 3 4	2 8 7	1 12 2	0 6 1	0 3 3	2 5 6
2	1 4 2	0 4 7	0 2 5	1 11 2	1 2 8	0 4 1	0 2 4	1 9 1

Carting from the material depôts to the roads costs, in addition to the above, about Rs. 1–6–0 per 100 cubic feet per mile.

(2) AVENUES.

Use of avenues.—Some difference of opinion exists as to whether trees overhanging a road are detrimental or beneficial to it. It is not necessary to consider the question whether they are or are not; the comfort derived by travellers and passengers from a well-planted avenue which thoroughly shades a road must give way to all considerations in regard to the "life" of the road. Shielding road surfaces from the baking action of the sun and thus retarding evaporation does, it is believed, add to the "life" of the roads, and *en passant*, it may be remarked that belts of trees have a considerable protective influence against malaria.

Planting.—In planting trees by the sides of roads, a good-sized pit (say about 4 feet cube) should be formed, the proper time for doing this being the hot season; the earth removed should then be sifted, mixed with manure and replaced ready for the planting which should be effected

shortly before the rains. Leaf mould kept in a pit until desiccated is a good substitute for manure.

When the tree is planted a mound ought to be raised round it a foot or a foot and-a-half high, an entrance being left for the water from the road.

Protection of trees.—The trees should be protected by fencing. A most effective fencing is bamboo thorns tied on to stakes of some jungle or other cheap wood, the enclosure should be kept free from grass weeds, &c., which are apt to choke the young trees.

Nature of trees required.—What are required in an avenue are primarily shade trees; some of these bear fruit and may thus become a source of revenue. In forming a new avenue, it is well to plant quick-growing shade trees alternately with trees which, though superior, take a longer time to come to maturity; rain trees for instance may be planted alternately with tamarind or banian trees.

The following is a list of some trees suitable for road avenues:—

Ficus indica (banian).	Slow growing, but giving good shade.
Ficus religiosa (peepul).	
Tamarindus indica (tamarind).	Good shade; fairly good wood, slow growing.
Margosa (neem)	A hardy quick-growing tree.
Tectona grandis (teak) ..	Large forest tree, very slow in growth.
Lagerstræmia reginæ (jarool).	A splendid tree with rose-coloured or purple flowers.
Pithecolobium saman (rain tree).	A very fast-growing tree.
Casuarina equisetifolia (casuarina).	A well-known fuel tree, quick growing.
Mangifera indica (mango)..	A shady fruit tree.
Melia indica (vepam) ..	Good shade trees in hot season, timber fairly good.
Melia azedarach (Persian lilac).	
Millingtonia hortensis (cork tree).	Sweet-scented flowering tree.
Acacia arabica (karuvélam).	Fairly shady trees.
Acacia leucophlæa (velvélam).	

Lands suitable for various trees.—In rice lands the banians grow well. In laterite the mango and acacia flourish; for sandy and gravelly soils the various kinds of

ficus are suitable; for black cotton soils the velams may be selected, while the casuarinas flourish in sandy soils.

Colonel Campbell-Walker's recommendation as to planting.—According to Colonel Campbell-Walker, late Conservator of Forests, Madras, avenues may be created by seedlings or from cuttings. Sowing "in situ" is out of the question if good results are to be obtained, owing to the watering required; cuttings of the figs grow well and make trees more quickly than seedlings.

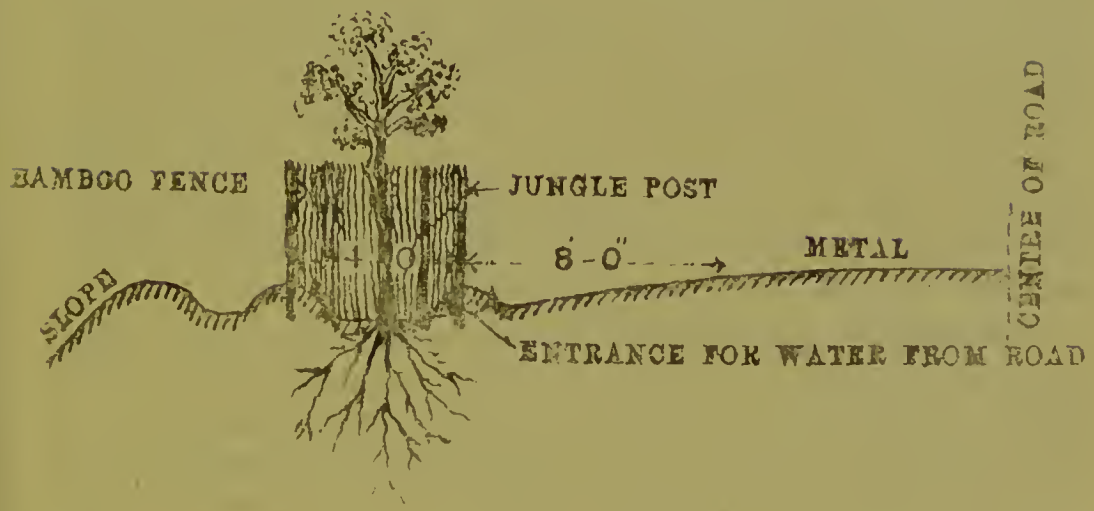
Pruning and watering young trees necessary.—To secure good results in avenue planting, it is necessary not only to select the species best adapted to the soil and climate and to establish the young trees, but to take great care in pruning them as they grow up. Lateral branches and suckers ought to be removed. The fences must be well maintained and the trees occasionally watered in the dry season until such time as they can thrive without such external aid.

Of the two following sketches, the first shows the plan above recommended for fencing and preserving the trees, the second, a system adopted at Palmanair, North Arcot, to which the objection seems to be that the mound, in which the tree is, must get very dry in the hot season and apt to be washed away in the wet season.

AVENUES

HALF SECTIONS OF ROADWAY

PLAN RECOMMENDED



PALMANAIR SYSTEM



(3) STREET LIGHTING.

Street lighting a preventive against commission of nuisances.—A few remarks on street lighting may not be altogether out of place in this work. It is neither a sanitary nor an engineering measure, but necessary for public convenience and security of property, &c. It is, however, in some respects an aid to sanitation, preventing to a greater or less extent the commission of nuisances by assisting the police to detect offenders.

Petroleum.—In Southern India it is improbable that for some time gas-lighting will be introduced, even though coal becomes very much cheaper than it is. In petroleum and its products, coal has a powerful rival, and the immense increase that has lately taken place in the production of petroleum, especially on the Caspian Sea, the likelihood of other places being found, which will yield a supply of oil, and the anticipated development of the Burma wells, should lead petroleum to be looked to rather than the former product as the future, as it is the present, source of light for our towns.

Possible illuminants.—Great developments will take place in the manner in which petroleum (in the form of kerosine) is now used, and it is probable that petroleum gas * may be in the early future a common illuminant in Southern India. On the other hand, petroleum may become so cheap as to allow of its being burnt as fuel in steam engines used for the production of the electric light, the present cost of fuel in Southern India being the greatest objection to the introduction of the latter.

Kerosine oil.—Situated as at present, kerosine oil is probably the only possible illuminant in towns and villages. It is an extremely cheap illuminant, and is preferable as regards cost and illuminating power to any vegetable oil.

Consumption of kerosine oil.—A 1-inch kerosine oil lamp gives a light equal to about 10 to 12 standard candles and requires for consumption 1·75 oz. of oil per hour = 1·4 pollams.

There are—

25 oz. to a bottle.
25 bottles to a tin.
50 do. to a case of two tins.
1,250 oz. to a case.

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* It is now in use in private houses and workshops in Madras.

Economy in street lighting.—India having the advantage of exceedingly bright moon-light nights, the following arrangement for town lighting is one which is probably suitable to the conditions of the country and no less suitable to the financial circumstances of Municipal Boards in general. "No public lamps to be lighted during the ten nights before full moon; the night after, to be lighted for one hour, and extinguished on the rising of the moon. The lighting to increase from night to night about three-quarters of an hour until the moon has entirely disappeared, when the lamps are lighted fully for ten consecutive nights. Again on the appearance of the new moon the lamps not to be lit until the moon sets, and this non-lighting time to increase nightly about three-quarters of an hour, according as the moon appears until ten nights before the date of full moon, when the procedure explained begins again. The lights always to be extinguished at midnight."

Contracts for street lighting.—If a contract is to be entered into for lighting a city, it is well to make out a table based on the foregoing principles, taking also into account the time the sun sets; thus suppose the sun sets at 6–30 P.M. and the moon rises at 7 P.M., it would hardly be thought necessary to light from 6 to 7 P.M., whereas when the sun sets at 6 P.M. it might be considered to be so. It will be found from such a table that the amount of lighting required per lunar month will vary from 90 to 98 hours.

Cost of lighting.—Taking 95 hours as the average, the amount of kerosine oil required per lamp during 28 days will be $\frac{95 \times 1{\cdot}75 \text{ oz.}}{25 \text{ oz.}} = 6\frac{2}{3}$ bottles, say 7 to allow for waste. Kerosine oil may be bought in Madras at Rs. 4–4–0 a case or Rs. 2–2–0 per tin, so that the actual cost for oil per lamp per month amounts to only $\frac{7 \text{ bottles} \times \text{Rs. } 1{\cdot}7}{25} = \text{As. } 9\text{–}6$ per lamp.

Madras rate.—In Madras when the lamps were lighted for only 95 hours per season the lanterns, burners, chimney frames, &c., were kept in repair and the lamps lighted as above for As. 10–5 per month, leaving 11 pies for labour in repairs and lighting and the supplying of wick. Lighting is now extended to 143 hours per season and under similar conditions as above, costs As. 11–9 per lamp per month.

Lanterns.—Lanterns ought to be made with the lightest possible metal, frames compatible with strength, the bars narrow, to avoid shadows and with a good outlet at the top for heated air. The door must be at one side. The top of the

lantern should be tin, not glass, or an amount of light is lost. Each lamp should be carefully numbered, so that lamp inspectors may readily note defects without having to add long descriptions of the position of the lamps.

Distance between lamps.—When determining the distance public lamps ought to be apart, it must be remembered that the intensity of light varies inversely with the square of the distance (thus a light is only one-fourth as intense 40 yards distant as when only 20 yards) and is directly proportional to the illuminating power.

Amount of illumination of any point.—The illumination at any point between lamps may be arrived at by adding all the quotients obtained by dividing the illuminating power in standard candles * of each lamp by the square of its distance in yards from that point (x). Thus if the point (x) is 20 yards from one lamp and 20 from another and each lamp gives a light equal to 12 standard candles, then the illumination at $x = \frac{12}{400} + \frac{12}{400} = \cdot 06$ candles.

Perfectly effective lighting.—The rule in England generally is that lamps burning 5 cubic feet per hour of 15 candle gas should not be placed at a greater distance than 60 yards. The average of distance in most English towns is 40 yards. As a kerosine lamp gives much less light, such lamps ought to be placed closer still, to give effective lighting, but as perfectly effective lighting (that is when a newspaper can be read in any part of the street) is likely to be found too expensive, the best method is to place the lamps at corners, changes of direction in streets, places shaded by trees, &c.

Distribution of light and height of posts.—The *distribution* of light is better in proportion to its height above the ground, but the *amount* of light thrown on the ground is greater as the light is lower. There is evidently therefore some point at which the two elements, distribution and amount, will, when considered together, be most effective, but to this consideration must also be added those economic ones of facility in lighting, cost of posts, &c. The usual height of a lamp post varies from 8 feet to 9 feet 6 inches with the lamp some 6 inches higher. This is a height easy to get at with a ladder, while the burner is sufficiently high to be out of the reach of mischievous persons who might interfere with it.

Posts and brackets.—Cast-iron lamp posts of plain pattern may be obtained in Madras at about Rs. 14–14–0

* A standard candle is one which is consumed at the rate of 1 inch per hour.

each, while posts of old rails can be fitted up for Rs. 8–12–0 to Rs 12–8–0. Iron brackets cost not much less than posts and are liable to much damage by carts highly laden or from the houses to which they are affixed being badly constructed. Wooden posts ought not to be used; they are liable to rot and fall without warning. The cost of a lamp post, lantern, &c., complete is as follows :—

Cast-iron Lamp Post.

	RS.	A.	P.
Lamp post, cast iron	14	14	0
Lantern frame	1	6	9
Lantern (street)	1	10	3
Moon, pine	0	10	6
Burner with collar (brass)	1	3	3
Zinc reservoir	0	3	1
Average fixing charges within municipal limits	1	0	0
Total ..	20	15	10

Old Rail Lamp Post.

	RS.	A.	P.
Lamp post, rail	8	12	0
Lantern frame	1	6	9
Lantern (street)	1	10	3
Moon, pine	0	10	6
Burner with collar (brass)	1	3	3
Zinc reservoir	0	3	1
Average fixing charges within municipal limits	1	0	0
Total ..	14	13	10

Inspection of lighting done by contract.—When street lighting is given out on contract, it is very desirable that there should be frequent inspection and it is well to come to a previous understanding with the contractor that for each defect found he shall be liable to a certain fine as a maximum ; for instance, lamps lit after time, put out before the proper hour, smoking burners, wick turned down too low, lantern dirty, frame shaky, too little oil in the reservoirs, are instances of faults which will be found under any contract for lighting. The quality of the oil to be used should also be previously fixed upon. Such details tend not only to be better ighting, but to the prevention of friction between a contractor and his employers.

CHAPTER VI.

BUILDINGS.

(1) BUILDING MATERIALS.

Classification.—Building materials may be classified as follows :—

(1) Stone, (2) bricks, (3) limes, (4) timber, (5) metals, and (6) paints and varnishes.

Under the head of bricks may be included tiles, pottery and artificial stones; under that of limes may be included cement and sand with their combinations mortar and concrete.

I.—Stone.

Stone suitable for building is found only within limited areas. The chief stones used for building in India are granite, gneiss, marble, limestone, slate and laterite. The qualities required in stone are so varied that no definite rule can be given as a guide in selection; a stone very suitable for an engineering work may be quite unsuitable for an architectural work. The principal qualities to be looked for in stone are its strength, durability and facility of working.

The durability of a stone is its power to resist the effects of the weather; this power is not always co-existent with strength, but often is so. One test of the durability of stone is its absorptive power; the best guide to the selection of stone is an examination of the existing buildings in the locality where a proposed structure is to be erected.

Preservation of stone.—Stone decays from various causes, and most of the processes in use for its preservation depend on the filling up of the pores of the stone at its exposed surface so as to exclude air and moisture. For this purpose coal tar is efficient, but unsightly. Boiled linseed oil may be used as a temporary expedient. The silicates of lime and potash are said to be effectual.

II.—Bricks.

Brick is the material mostly in use for buildings in India, its advantages being its comparative cheapness and

easy manipulation. Owing to the want of suitable clay in many localities, bricks sufficiently good for building purposes are not obtainable.

Bricks classified.—The manufacture of bricks is carried on so extensively all over the country that it is unnecessary to enter into details regarding the process. Bricks may be classified with reference to their mode of manufacture, into 'table-moulded bricks' and 'ground-moulded bricks.' The former are made on a table with metal or metal-lined moulds ; the latter are made on the ground, usually in moulds made of wood. The process of making table-moulded bricks is, in all its stages, more elaborate than that employed in making ground-moulded bricks, and requires better appliances and kilns to burn them. The native brickmaker seldom makes table-moulded bricks unless they are required for some special work in such large numbers as would pay him to undertake the extra expense involved. Table-moulded bricks have a more regular shape, a smoother surface and usually are larger than country bricks. The advantage of their regularity and smoothness of surface is, that, when they are used in buildings, the exterior of the walls may be left unplastered. This not only adds to the appearance of the work, but also saves the cost of plastering. The advantages due to their size will be enumerated below.

Characteristics of good bricks.—The quality of bricks depends on the nature and preparation of the clay, their shape, on the amount of care taken to dry and burn them. A good brick is characterised by its clear uniform colour, compact structure, regularity of surface and sharpness of edge, and by its clear ringing sound when struck. A really good brick ought not to absorb more than one-fifteenth of its weight in water, but native-made bricks absorb sometimes as much as one-fifth of their weight.

Bricks in reference to their use.—Bricks may be grouped according to their use as wall, arch, well, and terrace bricks. Wall bricks are rectangular in shape, their length is usually double their width and their thickness is from $1\frac{1}{2}$ to 3 inches. Arch and well bricks approximate in their dimensions to wall bricks, but the former are thicker at one side and the latter, broader at one end than at the other.

Economy of building with large bricks.—Though there is great economy in using thick bricks, a native kiln will not burn well, bricks, which are thicker than $1\frac{1}{2}$ inches or $1\frac{3}{4}$ inches. The economy due to the use of thick bricks is the lesser number required and therefore the less number of

joints in the work, the less quantity of chunam necessary, and, because a bricklayer can lay in a day as many thick bricks as he can thin ones, so that, where there are proper kilns where thick bricks can be thoroughly burnt, it is better to use such bricks.

Fixed dimensions desirable.—It is very desirable that there should be some fixed dimensions for bricks, otherwise in designing buildings and deciding upon the thickness of the walls much trouble is experienced. To allow of the bricks being properly bonded, adherence to the following rule ought always to be insisted upon :—

"The breadth of a brick ought to be one-eighth inch less than half the length of the brick," so that two breadths connected by a quarter-inch mortar joint will equal the length of a brick, thus an $8\frac{3}{4}$-inch brick should be $4\frac{1}{4}$ inches broad, and a 9-inch brick $4\frac{3}{8}$ inches, and so on.

Sizes of bricks.—Bricks are made of various sizes according to the fancy of the manufacturer, the wishes of the purchaser or the custom of the country. The following are the usual sizes available :—

Madras Government bricks ..	.. $9\frac{3}{4}'' \times 4\frac{3}{4}'' \times 3''$
Ground-moulded bricks, large	.. $9'' \times 4\frac{1}{2}'' \times 2''$
Do. small	.. $8'' \times 4'' \times 1\frac{1}{2}''$
Terrace bricks	.. $5'' \times 3'' \times 1''$

Artificial stone is used to a large extent in England and is very suitable for cornices, mouldings, &c. It is not much used in India; a simple artificial stone may be made of broken granite and hydraulic cement in the proportion of 4 granite to 1 cement with a small quantity of water, the blocks when set being placed for two days in a solution of silicate of soda. This stone is not adapted for fine classes of work, such as mouldings, &c.

Flooring tiles, ordinary, are made of clay similar to that used for ordinary bricks and are $1\frac{1}{2}$ inches to 2 inches thick and 6 inches to 12 inches square. These tiles do not present an even surface when laid, and the practice is to level them after they are laid by rubbing them down with a brick. A superior flooring tile is made at the Madras Government brick-fields. They are of clay similar to that used for bricks, but ground much finer. They are moulded in presses and have an oiled surface. These tiles do not wear out as easily as country tiles, but they cost more.

Stoneware tiles.—Messrs. Burn and Company of Calcutta manufacture stoneware flooring tiles in a variety of

shapes and sizes. They may be obtained either with plain or chequered surfaces, the latter being very useful for flooring engine and boiler rooms, markets, stables, or in any position where the floor is liable to be slippery owing to wet; they give a firm hold to the foot. This flooring is neat in appearance and as indestructible as stone, but is rather expensive, the cost in Southern India being about Rs. 80 per square.

Roofing tiles.—Of these there are various descriptions, viz., the ordinary pot tile made on the potters-wheel, the pan tile shorter and less curved than the former, the flat tile, the School of Arts tile and the Mangalore tile: the manner of using them will be described further on.

III.—Lime and Cement.

Limes may be divided into two classes, common and hydraulic.

Common lime may be either what is called fat lime or poor lime; the former is pure, in the latter there is a mechanical mixture of lime and inert matter like sand. Common lime will not harden under water.

Hydraulic lime contains silica, alumina, magnesia, &c., in chemical combination with lime in an aggregate proportion of 8 to 10 per cent. It possesses the valuable property of hardening under water.

Preparation of lime.—Lime is found in nature as carbonate of lime; sea shells, limestone, lime pebbles or 'kunkur' are formed wholly or in part of carbonate of lime. The process of manufacturing or burning of lime is simple. The stones or shells are placed in alternate layers with fuel in kilns and burnt. The action resulting from the calcination is the expulsion of the carbonic acid in the stone or shells, producing the quick-lime of commerce. To render it fit for building purposes, it is slaked or reduced to powder (hydrate of lime) by pouring over it water, in quantity, equal to about one-third of its bulk, the lime, at the same time, being thoroughly turned over with a shovel or hoe. A rich lime expands by the addition of water to twice its bulk, and then quickly falls to powder, while an hydraulic lime expands less in proportion to its hydraulicity and takes longer to fall to powder. The lime produced from shells is a rich fat lime. Lime obtained from stones is usually either poor or slightly hydraulic. Poor limes are characterised by a brownish colour, while hydraulic limes have greyish colour. A good hydraulic lime is unobtainable in Southern India. The best that has come under the writer's

notice is that made from coral stones obtained from the Devi Islands off the Malabar coast.

Slaked lime should not be allowed to stand unused for any length of time. To ensure this, lime should, as a rule, be obtained unslaked, and slaked on the works as required. This precaution will also be a safeguard against the adulteration of stone lime, which is not an uncommon practice.

Portland cement.—The use of Portland cement for works of a sanitary nature is rapidly increasing in this country. Portland cement is usually imported into this country from England, but large quantities are manufactured at the Madras Cement Works.

Tests for Portland cement.—It is usual to specify the following requirements for cement used in engineering works :—

(1) The cement shall weigh 112 lb. per bushel of 1·283 cubic feet.

(2) It shall be ground sufficiently fine to pass through a sieve of 2,500 meshes to the square inch, leaving a residue of not more than 10 per cent.

(3) It shall be capable of bearing a tensile strain of 350 lb. per square inch at seven days old, the briquette being immersed in water for 24 hours after having been moulded.

Choice of cement.—It is not within the power of the ordinary purchaser to carry out all of the above-indicated tests. For ordinary purposes, it will be sufficient if cement be obtained from some respectable local dealer who sells a well-known brand of English cement. Locally-made cement is not equal in strength to the best brands of imported cement, but it is cheaper and by using a higher proportion of cement, the same strength can be obtained as with English cement at the same cost if not less. Purchasers should however take two precautions in buying cement: *first*, with regard to imported cement, it should be observed whether the cement in the casks has slaked, as this indicates absorption and consequent deterioration of the cement; *secondly*, Indian cement should not be used as soon as it leaves the mill-stones, but should be warehoused for some time and allowed to cool before use. Cement undergoes a process called 'air-slaking' for a considerable time after manufacture; if it is used before 'air-slaking' has been completed, it will show a tendency to 'blow' and disintegrate. When the hand is plunged into a bag of cement, if it feels warm, it is an indication that 'air-slaking' is still proceeding. The less water used in mixing cement the

better. Bricks and stones used with cement should, however, be well soaked. Salt water is as good as fresh for mixing with cement. Good cement weighs about 87 lbs. to the cubic foot. The gross weight of a barrel of cement is 400 lbs. and the net weight of cement contained in it is about 383 lbs.

Artificial cement or soorki.—An artificial cement is made in India by mixing what is called soorki (three-quarters burnt brick well pounded until it has the appearance of sand) with lime. The best proportions are 1 of lime to 1 of soorki, but when rapid setting is required, the proportion of soorki must be increased.

Sand.—The sand used for building purposes should be clean and sharp, neither too large nor too small in grain, nor should the grains be of equal size. The more angular or 'sharp' the grains of sand are, the better will they key into each other when made into mortar; in addition they offer a larger surface for the adhesion of the lime or cement than if the grains are rounded. The purity of sand can be tested by placing it in a bucket of water and stirring it round; much discolouration shows it contains earth, clay or vegetable matter. Sea sand on account of the salt in it must be avoided unless with cement mortar.

Mortar or chunam * is a mixture of slaked lime or cement and sand, sufficient water being added to bring it to the proper consistency. Mortar is made by placing the requisite quantity of sand in a trench with the lime, the ordinary proportions of lime and sand being 1 and 2 respectively. This is beaten up by women or boys with chunam pounders.

Preparation of lime mortar.—For large works a circular trench is formed, and the mortar is then formed into a paste and ground by a heavy stone roller drawn by bullocks, or, if a pugmill is available, that mode of preparation is still better. Whatever method is used, the object is the same, viz., a thorough admixture of the lime and sand.

Preparation of cement mortar.—Cement mortar does not require to be pounded; careful mixing with the sand is sufficient. In mortar for masonry works the usual proportion is 1 of cement and 3 of sand by measure. The mixture should be made on a platform having a clean and hard surface. This is best made of planks or bricks laid edge to edge on the

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* This word is indiscriminately applied to the lime itself as well as to 'the mortar.'

ground. The sand which must be perfectly dry should be measured first and placed on the platform. The cement should be measured next and placed over the measured heap of sand. The two should then be thoroughly mixed *without the addition of any water* by turning the mixture over with shovels. Large heaps of sand and cement mixture should never be made into mortar at once by the addition of water. The addition of water to the mixture should be made at the spot where the bricklayers are working. The dry mixture should be taken to the bricklayers in quantities not exceeding one cubic foot. Each bricklayer should be provided with trays, or small boxes (dealwood wine cases serve the purpose) into which the mixture is thrown and water added to it, gradually working it at the same time with the trowel, until it is reduced to the proper consistency for use. The quantity of water to be added requires attention. The use of too much water should be avoided, because it reduces the strength of the mortar, and the desired plasticity should be obtained by well working it. Not more than one-third of its bulk of water is required for mixing cement mortar. Bricks and stones used with cement mortar should however be well soaked. Salt water is as good as fresh for mixing with cement. As soon as the mortar is made, it should be used up and not allowed to partially set on the board and to be beaten up again, for this only destroys the cement and renders it of no value whatever. Cement, when it has once commenced to set, cannot advantageously be worked up again.

Preparation of soorki mortar.—The best proportions for soorki mortar are 1 of lime, 1 of sand and 1 of soorki, but, when rapid setting is required, the proportion of soorki must be increased with a corresponding decrease in the quantity of sand. Soorki mortar ought not to be used unless it is to be immersed or kept very moist for at least a month.

Sugar in mortar.—Attention has lately been called in England to the use of sugar with lime mortar. The custom of mixing jaggery (molasses) in India is a common one. One pound to each eight gallons of water to be used for mixing the lime will be found sufficient. It must not be used with soorki mortar.

Lime plastering.—Plastering in India is probably carried out to too great an extent, but ordinary country brickwork requires its use to take away the rough and unfinished appearance a building otherwise would have. When, however, good bricks are used and the courses are well and neatly

laid, plastering ought to be omitted. For comfort and appearance the walls of the living rooms of houses in India are usually plastered. Plaster, as made in India, is very much the same as mortar, though perhaps more finely ground. Plastering is done in one, two or three coats. The following proportions are used in Madras :—

——	First coat.	Second coat.	Third coat.
One coat of plaster.	1 chunam ... 1½ river sand.	... ...	
Two coats of do.	1 chunam ... 1½ river sand.	2 chunam. 1 white sand.	
Three coats of do.	1 chunam ... 1½ river sand.	1 chunam ... 1 sand ...	4 chunam. 1 white sand.

Fresh water and sand must, in all cases, be used.

The following is the process of plastering walls in Madras :—

For one coat, the plaster is composed of one part of lime and one and-a-half of river sand, thoroughly mixed and well beaten up with water. Before applying the plaster, the wall should be trimmed with a trowel, and swept perfectly clean and then sprinkled with water. The wall being ready, the plaster is mixed up with jaggery-water and brought to the required consistency. It is then laid on with a trowel, about half an inch thick, and levelled with a flat wooden rule, being afterwards smoothened with a wooden rubber, till it acquires an even surface. During the process of rubbing, the plaster is occasionally sprinkled with a little pure lime mixed with water to give it a hard and even surface.

For two coats, the first coat is applied as already described, with the exception that the surface is left rough, and no pure lime is applied during the process of rubbing. A day or two after the first coat is put on, and while it is still moist, the second coat is applied. The plaster used for the second coat consists of two parts of lime and one of *white* sand. They are mixed as before, and afterwards ground on a flat stone, with a small stone roller * till they are reduced to a fine paste. The plaster thus prepared is laid on a wooden rubber and applied with care, over the first coat, about an eighth of an

* Mortar for cut-stone work is ground on a stone in the same way.

inch thick. It is then rubbed down perfectly smooth, with a small trowel, and afterwards polished with a crystal or smooth stone rubber, and as soon as it has acquired a polish, a little very fine *ballapum* * (soap-stone) powder is sprinkled on it to increase the whiteness and polish of the plaster, and the polishing continued. The second coat ought to be applied and finished in one day, for it usually hardens too much during the night to be polished the following day, unless in damp weather. The practice is to continue polishing the plaster until it is quite dry, and a number of bricklayers are employed in order that it may be well polished the first day. Moisture continues to exude from the plaster for some days after it is completed; this ought to be carefully wiped off with a fine cloth and the wall kept perfectly dry till the moisture ceases.

For three coats, the first is laid on as already described, but it is left a fortnight or three weeks to dry before the second coat is applied. The plaster for the second coat consists of one part of lime and one of fine river sand, freed from the coarser particles and from clay by sifting. It is well mixed and beaten up in a clean trough and applied over the first coat about a quarter of an inch in thickness, the first coat being previously moistened with a little water. It is next rubbed down in the same manner as the first coat, but acquires a much smoother surface, the plaster being of a finer quality. A day or two afterwards before it has had time to dry, the third coat is applied. It consists of four parts of lime and one of fine *white* sand. These, after being well mixed and reduced by grinding to a very fine paste, quite free from grittiness, are put into a large earthen jar, of the size nearly of half a hogshead, and mixed with the whites of eggs and tyre or milk curds, in the proportion of 12 eggs and 1½ measures of tyre to every parah of plaster.† These are all mixed and rubbed between the hands, till the ingredients are thoroughly incorporated, and the composition reduced to a uniform consistent paste, a little

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* The ballapum powder is tied up in cloth, and dusted over the wall, as pumice is applied to paper, by which means, the finest parts only are used. Ballapum is the Canarese and *mavoo kulloo*, the Tamil name of pot-stone or soap-stone (steatite), which is a softish stone of a greyish-blue colour, found in many tracts of lower India, particularly in Mysore. It is easily worked, and is used by the natives for making small pots and dishes, and also pencils for school boys to write upon books with, which books are formed of cloth blackened and stiffened with gum. There is a variety of this stone which is more hard, and is called in Mysore *sila kulloo*, from the circumstance that it is generally used for making images.

† Sometimes half a pound of ghee is mixed with the above quantities of white of egg and tyre; other proportions of the ingredients are in use.

thicker than cream and perfectly free from grittiness. The plaster is now fit for use and is put on, with a wooden rubber, about a tenth of an inch thick, and gently rubbed till it becomes perfectly smooth. Immediately after this, another coat of still finer plaster is applied, consisting of pure lime ground to a very fine paste, and afterwards mixed with water in a clean tub till it is of the consistency of cream. This is put on about a sixteenth of an inch thick with a brush and rubbed gently with a small trowel till it acquires a slight degree of hardness. It is then rubbed with a crystal or stone rubber till a beautiful polish is produced, not forgetting to sprinkle the wall with fine ballapum powder during the process of polishing. If the plaster is not entirely dry on the second morning, the operation of polishing ought to be continued until it is quite dry. The moisture, as above directed, must be carefully wiped off and the wall kept quite dry till all appearance of moisture ceases. The quality of chunam depends chiefly on the plaster for the upper coat being reduced to a very fine paste, perfectly free from grittiness, and on its being, after it is applied to the wall, rubbed constantly with great care, till it is quite dry and has acquired a very fine polish. The wall ought then to be frequently wiped with a fine clean cloth to remove the moisture, and it may be occasionally dusted with ballapum powder. The stone used in polishing is a crystal or white pebble or piece of soap-stone, about 3 inches long and $1\frac{1}{4}$ inches broad with a perfectly smooth face. In the upper coat, very white sand only is employed, as common sand destroys the brilliancy of the plaster. When white sand is not procurable, white crystal, or pebbles reduced to a fine powder may be substituted. The thickness of plaster is from three-quarters of an inch to an inch, and is made so great in order to conceal irregularities in the face of the wall, but it would be stronger and last longer if the thickness did not exceed half an inch. In outside plastering, it will be better to follow the wavy outline of the wall than put an inch or more in the hollows to produce a perfectly level surface.

The proportion of lime to sand in the first coat is no doubt greater than it should be, and as it is the lime paste and not the sand that shrinks in drying, the plaster cracks owing to the excess of the former. The lime for plaster should be thoroughly slaked and carefully sifted, and the mortar should never be used quite fresh, for the particles, not perfectly slaked, by subsequently expanding or slaking in the wall, disturb others in their vicinity, and cause them to be detached or fall off. Keeping the mortar for some days insures the thorough slaking of the lime. It is desirable also that the shells and sand should be

washed in order to free them from saline particles, or other impurities, and no brackish water should be used in any of the subsequent processes. The plastering of the Madras Cathedral is deservedly celebrated, and though executed nearly sixty-eight years ago, it is still in excellent preservation. On that occasion, not only were all the precautions just mentioned taken, but the rubbing of the surface was carried on for a long time, and persons were employed for two months removing every appearance of moisture from the walls. Comparing this with the practice of the present day, it is not difficult to account for the quick deterioration of the plaster that now takes place.

Replastering.—Before replastering a wall or portion of a wall, it is necessary that the old plaster should be first entirely removed, the joints raked out to a depth of half an inch, and the surface of the wall wetted. If these precautions be taken, the plaster will adhere firmly to the wall, but if neglected, it is apt to fall off in flakes. The bricklayers have a very slovenly way of roughly pointing the walls, as they are being raised, with the mortar squeezed out by each brick as it is laid, by which means, nearly the whole surface of the wall is covered with plaster, portions of brick appearing only here and there. It is impossible that the first coat of plaster can adhere as well to such a surface, as it would, were the joints left open.

Cornices.—In forming cornices, the intended shape should first be given as nearly as possible by bricks * projecting from the face of the wall, so that only a small quantity of plaster will afterwards be required to complete it. Bold projecting cornices formed entirely with common mortar, as they often are, cannot possibly be durable.

Cement plastering.—Cement plaster should always be laid on in a *single* coat of the required thickness. The usual proportions for cement plaster are 1 of cement to 3 of sand or 1 of cement to 2 of sand. Before applying the plaster the joints should be raked out, the walls swept and thoroughly wetted. Where a rough surface is not objectionable, the plaster should be rubbed down with a wooden float. Where a smooth surface is desired, the surface of the plaster should be sprinkled with neat cement and rubbed down with a trowel. Cement plaster for walls should not be less than one quarter inch thick, nor is it desirable to have a thickness

* Bricks, 18 inches in length, are sometimes made expressly for cornices.

greater than half an inch. Owing to the want of plasticity in cement mortar, a very thick coat of plaster does not hold to the wall when first laid; it is apt to slip down. The thickness of plaster for floors should not be less than half an inch, and it need not exceed three-fourths of an inch. Cement plaster should be kept wet for at least a week after being laid.

White-wash should be prepared from fresh burnt white lime stone or shell lime. The lime is dissolved in a tub with sufficient water; clean gum dissolved in hot water is then added in the proportion of 2 ozs. of gum arabic to 1 cubic foot of lime, or rice size may be used in place of gum. The white-wash should be so thick that it does not readily drop from the brush; to ensure a uniform wash, English brushes should be used; the native brush formed from the root of a bush called *tashum cheddy*, the end of which is beaten out, gives a very uneven appearance. White-wash is usually applied in three coats. From walls which have been once white-washed, the old white-wash should be scraped and the wall brushed clean before the new white-wash is laid on.

Blue and other washes.—Blue, yellow and red washes are made by mixing ground burnt cocoanut shells, yellow ochre and red ochre, respectively, with white-wash prepared as described above.

Pointing.—Where it is not necessary to plaster a building, the joints of the brickwork may be raked out, the brickwork cleaned and the joints then refilled with a paste of finely ground cement and sand. The work to be effective must be neatly done.

Concrete is a mixture of mortar and gravel, pebbles, broken bricks, or broken stones. The material that enters into combination with mortar to form concrete is called the aggregate. The best aggregate for forming lime concrete is broken brick and for cement concrete broken stone. Owing to their roundness gravel and pebbles are not desirable materials for forming concrete.

Size of aggregate.—For the foundations of buildings and bridges, the aggregate should be broken to a size such as will pass through a ring $1\frac{1}{2}$ to 2 inches in diameter. For flooring purposes the size should not exceed 1 inch. The bricks or stones should be broken, as far as possible, into cubes of the required size.

Proportion of mortar.—The proportion of mortar to the coarse material must be determined on the principle that the volume of the cementing substance should always be slightly

in excess of the voids to be filled; if the materials to be united be a coarse gravel of an average size of two inches, each cubic yard gives 11 cubic feet of void, and the result of an experiment made in Madras with small gravel varying from half an inch to one inch showed that a well-filled parah of the above material could contain 60 lbs. or nearly one cubic foot of water without leaking or overflowing. The former proportion is $\frac{11}{27} = \cdot 41$, the latter $\frac{1}{2 \cdot 31} = \cdot 43$. In practice, however, a little more mortar than the volume of voids is used. The usual proportion is 50 per cent. of the volume of the aggregate.

Proportion of materials.—In making concrete, the amount of sand to lime or cement should first be determined. The following proportions are recommended for ordinary municipal works:—

For chunam concrete—
Broken bricks 4, sand 2, slaked lime 1.

For cement concrete—
Broken stones 6, sand 3, cement 1.

For the blocks for the inverts of the Madras sewers, the following proportions were used:—

Gravel $6\frac{3}{4}$, sand 3, cement 1.

These had thoroughly set before being used. For the Madras Harbour Works blocks, the following are the proportions:—

Stone 5, sand $2\frac{1}{2}$, cement 1.

The best proportion must, however, in all cases be determined experimentally.

Preparation of lime concrete.—Concrete should be mixed on a platform. The lime and sand must first be mixed into a stiff mortar with a small quantity of water. The aggregate should be separately wetted with as much water as is required to saturate it. The aggregate and the mortar should then be thrown together in alternate layers in the proportion of 2 buckets of the aggregate to 1 bucket of mortar; it is then to be thoroughly turned over with shovels.

Preparation of cement concrete.—The cement and sand should first be mixed thoroughly dry as described for cement mortar. The dry mixture should then be added to the aggregate and these two should be turned, with shovels, twice over without any water. When all the ingredients have been thoroughly mixed dry as above, water should be

added through the rose of a watering pot. The volume of water required will probably be about half the volume of cement.

Mode of laying concrete.—Concrete should always be prepared just before it is required for use. There is, however, not much objection to chunam concrete standing a few hours before being used. But cement concrete should, on no account, be allowed to do so and should be used up immediately after it is prepared. Concrete must not be thrown in from a height so as to cause the heavier particles to fall to the bottom. The consolidation should be effected by ramming. The concrete should be laid in the work in layers not exceeding 6 inches in depth and should be well rammed with wooden rammers. Chunam concrete will bear ramming for a day or two after being laid. Cement concrete should not be rammed for longer than 3 or 4 hours after being laid: it should then be left undisturbed.

Uses of concrete.—Ordinarily concrete is useful in foundations, paving, flooring and terracing, for filling in between the haunches of arches, for filling voids in rubble or rough stone work, for sealing wells, &c. Concrete is, however, now-a-days almost universally used in works, but its application requires much care. Cement concrete, or concrete mixed with hydraulic lime should alone be used for sub-aqueous works. The manufacture of flooring and paving stones, curb and plinth stones, cornices, pipes for sewage and water, &c., in cement concrete is an increasing industry.

IV.—Timber.

Timber.—This expression is applied to wood of a sufficient size for building or engineering purposes and is not less in girth than 24 inches. When the wood is in the living tree, it is *standing timber*, when felled, *rough timber*, and when cut up for use, simply *timber*, or is described according to its dimensions as logs, beams, balks, scantlings, planks or boards.

Structure.—All timber trees proper are exogenous, that is, they increase in girth by addition to their external surfaces of rings of young wood; palms and trees of that class are endogenous, because, though the tree grows partly by the addition of external layers, the fibres of the new wood cross and interweave themselves with the old.

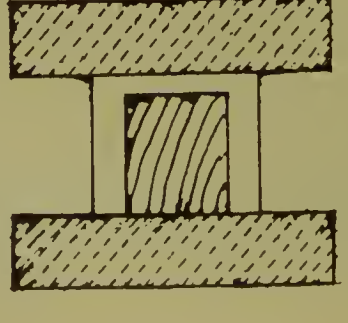
Time for felling timber.—In the spring the sap is rising in the tree until the new leaves are formed: in the autumn the sap descends and vegetation then ceases until the

following spring. The best time therefore for felling trees is when they are in a quiescent state, viz., in tropical climates, the dry season; then the timber is felled; it ought to be squared so as to expose it to the air and thus hasten its drying.

Durable timber.—The strongest timber is, in general, that which has grown most slowly as shown by the narrowness of the annual rings. Darkness of colour in a wood is, in general, a sign of strength. Freshly-cut wood should be firm and shining. A chalky appearance is a sign of bad timber. The heavier specimens of a wood are, in general, more lasting than the lighter.

Preservation and protection of timber.—Timber lasts longest when kept dry in a well-ventilated place. Wet timber is softened and weakened, but does not necessarily decay. Some timbers useless in air however are very useful under water; the cotton tree is an example of this class. Alternate wetness and dryness is bad for timber. Slaked lime destroys timber. Timber has not only to be preserved from moisture and from internal decay (dry rot), but in this country from the attacks of insects. Many processes for protection are used. Oil paint preserves timber from moisture, while saturation in chloride of zinc, sulphate of copper, creosote, &c., preserves it against insects. The last-named preparation is forced into the timber at a pressure of 150 lbs. per square inch after the air has been extracted from it, and the timber absorbs one-ninth to one-twelfth of its weight of oil. Railway sleepers are treated by this process. The chief woods which resist the attacks of insects without treatment are teak, sâl, and eyne.

In building wood work into masonry the following precautions are necessary. Beams must be so fixed that no chunam comes in contact with them. The ends of beams must rest on bed plates, the bearing surface of which must be thoroughly dressed. A clear space of one-half to one inch must be left between the masonry and the beam at sides and top as shown below :—



Joists, windows, doors and other wood work, where contact with masonry is unavoidable, should have their surfaces in contact coated with boiling coal tar before being fixed. All exposed surfaces of wood work must either be painted or wood-oiled.

Building Timbers.—The following table includes some of the more useful building timbers and gives the uses to which such timbers are put:—

Botanical name.	Ordinary designation.	Remarks as to description, use, &c.
Acacia Arabica.	Babool, karu vélam.	A yellow-flowered tree; grows rapidly; thrives in poor soil; wood close-grained and tough; of a pale red colour; used for spokes, naves and felloes of wheels, ploughs and tent pins.
Acacia leucophlæa.	Vel—vélam...	Of the same description and used for the same purposes as the babool.
Acacia speciosa.	Sirris ...	Handsome foliage and sweet-scented tree, suitable for avenues; the wood is strong, hard and durable; does not crack or warp; used for naves of wheels, pestles and mortars.
Artocarpus integrifolia.	Jack ...	Useful fruit and timber tree; the wood is dry and brittle; suitable for house carpentry, tables, &c.; the wood is of a yellow colour.
Azadarachta indica.	Neem ...	Grows in the stoniest soil; wood is hard and durable; used for agricultural and building purposes; long beams are not obtainable, but for doors and door frames it is suitable.
Bambusa ..	Bamboo ...	Useful for scaffolding, ladders, roofing, chairs; can be obtained up to 60 feet in length and 8 inches in diameter. It is an endogenous timber.
Berrya ammonilla.	Trincomalle wood.	Indigenous to Ceylon; Madras Masoola boats are made of this; it is useful for furniture, shafts, helves, &c.; it is strong, light and flexible.
Bombax heptaphyllum.	Red cotton tree.	Light grained wood used for packing cases, tea chests, &c., and does not rot in water.
Borassus flabelliformis.	Palmyra ...	The leaves are used for thatching, mats, baskets, &c.; the timber, when the soft parts are removed, is durable and used for rafters, joists, &c.
Briedelia spinosa.	Muluvengay.	A tough-grained, close, durable wood suitable for well curbs, carts, and also used for railway sleepers.
Casuarina muricata.	Casuarina (chouk).	A fir-like tree; furnishes poles for scaffolding, &c.

Botanical name.	Ordinary designation.	Remarks as to description, use, &c.
Chickrassia tabularis.	One of the trees called 'Chittagong' wood.	Strong and tough; liable to warp; much used for furniture.
Chloroxlon swietenia.	Satin wood ...	Like 'box', obtainable in logs 18 feet long and 6 feet girth; hard durable wood; used for posts, rafters, naves of wheels.
Cocos nucifera.	Cocoanut palm.	Can be used for rafters, posts, water troughs, &c.
Dalbergia latifolia.	Malabar blackwood.	Used for all sorts of furniture, gun carriages, &c.; a most valuable timber.
Dalbergia sissoo.	Sissoo ..	A beautiful and useful tree; best Indian wood for Joiners' work, tables, chairs, furniture, &c.
Diospyros ebenum.	Ebony ...	The heart wood is deep black; used in veneer and cabinet work.
Emblica officinalis.	Nellikai ...	Useful for furniture, boxes, veneering and for well curbs; does not decay under water.
Eucalyptus ...	Blue gum ...	Chiefly used for firewood; suitable for scaffolding, poles, &c.
Feronia elephantum.	Wood apple ...	Furnishes the gum known as East India gum arabic; used in house and cart building and sometimes for railway sleepers.
Ficus indica.	Banyan ...	The wood is light and brittle and neither strong nor durable except under water; it is therefore used for well curbs.
Ficus religiosa.	Peepul ...	Has similar characteristics to the banyan.
Inga lucida ...	Iron wood ...	This is a fine foliage tree; the heart wood is black and termed iron wood.
Lagerstrœmia Reginæ.	Jarool ...	A handsome flowering tree; the wood is extensively used for boat, cart and house building, for gun carriages, &c.
Mangifera indica.	Mango ..	Wood of inferior quality; decays if exposed to wet; readily destroyed by insects; unsuitable except for temporary purposes.
Phœnix sylvestris.	Date palm (wild).	Trunks used for temporary revetment, piling, &c.
Pongamia glabra.	Karanj ...	An excellent avenue tree; the wood is light, tough and fibrous; does not take a smooth surface; used for solid wheels.
Psidium pomiferum.	Guava ...	Furnishes a grey, hard, tough light wood; fine-grained; useful for wood engraving and for handles for scientific instruments.
Pterocarpus dalbergioides.	Padawk ...	Furnishes a red mahogany-like timber; used for cart wheels and ordnance carriages.

Botanical name.	Ordinary designation.	Remarks as to description, use, &c.
Santalum album.	Sandalwood.	Used for making boxes, small articles of ornament; its odour is a preventive against insects.
Shorea robusta.	Sâl	The most useful timber for engineering purposes; useful for roofs, ship-building, houses, sleepers, &c.; the timber is straight, strong and durable, but it seasons slowly.
Tamarindus indica.	Tamarind ...	A handsome tree for avenues, wood hard and close-grained; used for turnery, oil-presses, mallets, &c.; a good wood for burning brick fuel.
Tectona grandis.	Teak ...	The most useful and durable timber; it is hard but light and easily worked, porous, strong and durable; used for every description of house-building, carriages, ships, &c.
Terminalia arjuna.	Vella marudu.	A magnificent avenue tree; furnishes a dark, brown, heavy wood suitable for masts, spars, beams, &c.
Terminlia tomentosa.	Eyue ...	A valuable forest tree of Malabar, Nagpore and Oudh; supplies heavy strong, durable and elastic wood; suitable for joists, beams, tie-rods; sometimes sold as 'Sâl,' but not equal to that wood.
Thespesia populnea.	Portia ...	Makes a fair avenue tree; timber not much used except for firewood; used sometimes for gun stocks and furniture.

V.—Metals.

The principal metals used in buildings in India are iron, steel and zinc.

Iron.—There are two distinct varieties of iron; one is a granulated or crystallized metal, called cast iron, the other is a fibrous metal or wrought iron. Iron in its various forms is coming more and more into use daily in connection with buildings.

Cast iron.—Cast iron is of two classes, grey and white. The grey description is softer and more easily fusible than the white; the white, though difficult to melt, is brittle and hard; grey is the best for castings. Colour and texture are the indications of good cast iron; recent fractures should show a

uniform light bluish grey colour; if the surface be mottled with crystalline patches, such castings are not satisfactory. When tested with a heavy hammer on their edges, castings should show slight indentations; splintering indicates brittleness and deficiency in strength. Cast iron is hard, brittle, readily fusible, but not forgeable or weldable. It is liable to break suddenly without warning. Owing to the nature of its properties, it lends itself easily to the manufacture of monolithic and ornamental articles, such as beams, pipes for water-supply, covers and gratings for manholes, lamp posts, ornamental railings, casings for fountains and valves, &c.

Wrought iron.—Wrought iron is iron from which the silicon and carbon have been removed. A fracture should show a fine close fibrous structure free from crystallization with a clear bluish grey and silky lustre. Wrought iron is soft, malleable, ductile, weldable, easily tenacious, stretches before breaking and is not fusible except at high temperatures. The principal forms of wrought iron are—

Flat iron	▬
Square or bar iron	■
Rod or round iron	●
Tee iron	T
Double Tee iron	I
Angle iron	L
Channel iron	⊔

Steel.—Steel is iron, with from $\frac{1}{2}$ to $1\frac{1}{2}$ per cent. of carbon. It is coming into general use as a building material, as it is daily becoming cheaper, and is used for girders, beams, rails and sleepers; it is in general use for machine tools.

Weight.—Cast iron weighs about 451 lbs., wrought iron 485 lbs. and steel 499 lbs. per cubic foot. In 'Engineering notes' will be found the weights of some of the most useful sizes of the various forms of iron.

Preservatives.—Iron work is prevented from rusting by coating the surface with boiling tar or painting with oil paint renewed from time to time.

Wrought iron joists.—Beams of the **I** section are now used to a great extent in place of wooden joists and beams.

The following table gives the safe load distributed for various spans of rolled iron beams:—

Sectional dimensions. Inches.	Weight per foot. lbs.	Safe permanent distributed loads in tons on the following spans, which represent the distances between supports.										
		6 ft.	8 ft.	10 ft.	12 ft.	14 ft.	16 ft.	18 ft.	20 ft.	22 ft.	24 ft.	26 ft.	28 ft.
3 × 3 × 3	10	$1\frac{8}{20}$	$1\frac{4}{20}$	$\frac{18}{20}$									
4 × 2 × 2	7	$1\frac{7}{20}$	$1\frac{3}{20}$	$\frac{17}{20}$									
4 × 3 × 3	12	$2\frac{7}{20}$	$1\frac{17}{20}$	$1\frac{8}{20}$	$1\frac{3}{20}$	1							
5 × 3 × 3	13	$4\frac{6}{20}$	$3\frac{2}{20}$	$2\frac{8}{20}$	$2\frac{2}{20}$	$1\frac{15}{20}$	$1\frac{10}{20}$						
5 × $4\frac{1}{2}$ × $4\frac{1}{2}$	23	$5\frac{18}{20}$	$4\frac{11}{20}$	$3\frac{10}{20}$	$2\frac{16}{20}$	$2\frac{9}{20}$	$2\frac{4}{20}$	2					
6 × 5 × 5	27	$8\frac{16}{20}$	$6\frac{9}{20}$	$5\frac{2}{20}$	$4\frac{6}{20}$	$3\frac{10}{20}$	$3\frac{3}{20}$	$2\frac{15}{20}$	$2\frac{8}{20}$				
$6\frac{1}{4}$ × 2 × 2	11	$3\frac{9}{20}$	$2\frac{10}{20}$	$1\frac{18}{20}$	$1\frac{12}{20}$	$1\frac{8}{20}$	$1\frac{3}{20}$	1	$\frac{10}{20}$				
7 × $3\frac{3}{4}$ × $3\frac{3}{4}$	20	$6\frac{16}{20}$	$5\frac{1}{20}$	$3\frac{18}{20}$	$3\frac{7}{20}$	$2\frac{17}{20}$	$2\frac{10}{20}$	$2\frac{4}{20}$	2	$1\frac{15}{20}$			
8 × $2\frac{1}{2}$ × $2\frac{1}{2}$	15	$7\frac{6}{20}$	$5\frac{13}{20}$	$4\frac{10}{20}$	$3\frac{12}{20}$	$3\frac{4}{20}$	$2\frac{15}{20}$	$2\frac{10}{20}$	$2\frac{4}{20}$	...			
8 × 4 × 4	22	$12\frac{5}{20}$	9	7	6	$5\frac{6}{20}$	$4\frac{11}{20}$	$4\frac{2}{20}$	$3\frac{12}{20}$	$3\frac{5}{20}$	$2\frac{15}{20}$		
8 × 5 × 5	29	$14\frac{5}{20}$	$10\frac{16}{20}$	$8\frac{10}{20}$	$7\frac{2}{20}$	6	$5\frac{6}{20}$	$4\frac{14}{20}$	$4\frac{4}{20}$	$3\frac{15}{20}$	$3\frac{8}{20}$		
8 × 6 × 6	34	15	11	9	$8\frac{10}{20}$	$6\frac{10}{20}$	$5\frac{15}{20}$	5	$5\frac{10}{20}$	4	$3\frac{10}{20}$		
$9\frac{1}{4}$ × $3\frac{3}{4}$ × $3\frac{3}{4}$	24	$13\frac{5}{20}$	$10\frac{6}{20}$	$8\frac{3}{20}$	$6\frac{11}{20}$	$5\frac{15}{20}$	$5\frac{2}{20}$	$4\frac{6}{20}$	$3\frac{18}{20}$	$3\frac{11}{20}$	$3\frac{4}{20}$		
10 × $4\frac{1}{2}$ × $4\frac{1}{2}$	30	$21\frac{15}{20}$	$16\frac{1}{20}$	$11\frac{12}{20}$	10	$8\frac{10}{20}$	$7\frac{15}{20}$	$6\frac{7}{20}$	$5\frac{10}{20}$	$5\frac{3}{20}$	$4\frac{8}{20}$	$3\frac{15}{20}$	3
10 × 5 × 5	36	$27\frac{5}{20}$	$21\frac{10}{20}$	$15\frac{18}{20}$	$13\frac{2}{20}$	$11\frac{2}{20}$	$10\frac{1}{20}$	$9\frac{3}{20}$	$7\frac{15}{20}$	$6\frac{8}{20}$	$5\frac{18}{20}$	$5\frac{6}{20}$	$4\frac{18}{20}$
10 × 6 × 6	50	30	23	$18\frac{15}{20}$	15	13	11	10	9	8	7	$6\frac{15}{20}$	6
12 × 5 × 5	42	$31\frac{15}{20}$	$23\frac{15}{20}$	$19\frac{8}{20}$	$15\frac{17}{20}$	$13\frac{16}{20}$	$11\frac{16}{20}$	$10\frac{14}{20}$	$9\frac{12}{20}$	$8\frac{13}{20}$	$7\frac{15}{20}$	$7\frac{2}{20}$	$6\frac{13}{20}$
12 × 6 × 6	56	$47\frac{10}{20}$	$35\frac{16}{20}$	$28\frac{7}{20}$	$23\frac{13}{20}$	$20\frac{13}{20}$	$17\frac{17}{20}$	$15\frac{18}{20}$	14	$12\frac{12}{20}$	$11\frac{18}{20}$	$10\frac{18}{20}$	10

These calculations are based on the assumption that the iron in tension will break at 20 tons per square inch, and the safe loads are taken at a quarter the breaking weight. The figures are theoretically correct.

Steel beams may be taken as 25 per cent. stronger than the same section in iron.

Corrugated iron is formed of wrought iron sheets rolled into an undulating or wavy surface which adds much to its strength and stiffness. It is used for a variety of purposes, amongst others for roofing, for walls of latrines, warehouses and buildings of a semi-permanent nature. Corrugated iron sheets are always coated with zinc to prevent rusting and then they are called galvanized corrugated iron sheets. They are procurable in various thicknesses and are usually sold in sheets of 6, 7, 8 feet lengths and 27 or 32 inches in width.

Approximate weights of Galvanized Iron Sheets.

Length.	Sheets 27 inches wide.			
	B.W.G. 18.	B.W.G. 20.	B.W.G. 22.	B.W.G. 24.
	LBS.	LBS.	LBS.	LBS.
6 feet	32	25	20	16
7 do.	37½	30	23½	19
8 do.	43	34	26½	21½

Length.	Sheets 32 inches wide.			
	B.W.G. 18.	B.W.G. 20.	B.W.G. 22.	B.W.G. 24.
	LBS.	LBS.	LBS.	LBS.
6 feet	38½	30	24	19¼
7 do.	44½	36	28	23
8 do.	51½	40½	32	26

VI.—Paints and Varnishes.

Painting.—Paints may be obtained at small expense in tins ready for use, or in powders which require to be ground up with oil; linseed oil is that most generally used. Care should be taken to see that all new wood work to be painted has been cleaned with sand paper and pumice stone and all projections and spots such as are due to glue or plaster removed. Nail heads should be well driven and covered with putty (whiting and linseed oil). Every coat of paint should be perfectly dry before a succeeding one is laid on.

Painting old wood work.—When old wood work has to be painted, it should be well rubbed down with soap and water or with lime water. All old paint on any work should be removed before new paint is laid on. This can be done by running over it with a hot iron and blistering it, or by means of special apparatus for the purpose.

Distempering.—Distemper work is much used in decorating buildings. The chief difference between distempering and painting is that in the former the colours are mixed with water instead of oil. It is cheaper but much less durable and will not bear washing.

Varnishes.—Varnishes are resinous substances which dry rapidly. Wood oil is the most common in use and next to it copal varnish. They are used instead of paints and applied in a similar manner.

(2) CONSTRUCTION OF BUILDINGS.

To consider all the most efficient and approved methods of designing and constructing the varied descriptions of buildings which appertain to sanitary works would require the limits of this publication to be extended far beyond what is proposed. It will be sufficient to describe details such as are found in ordinary buildings and to add some practical rules to guide sanitary authorities in proportioning the various parts of a building and aid them in the selection and economical combination of the materials which have already been described.

Brickwork.

Descriptions of brickwork.—Two descriptions of brickwork are common in this country, viz., brickwork in mud or clay and brickwork with chunam mortar; in special works brickwork in soorki or cement is also used.

Brickwork in mud or clay.—Brickwork in clay may be used in the inferior class of buildings, such as huts, compound walls, &c.; it is not deficient in strength, but affords an easy passage for white ants to the roof timbers. It may be plastered with a mixture of clay and sand or chunam mortar. Mud walls, whether forming part of buildings or not, ought always to be coped with brick in chunam, and buildings with mud walls should have their eaves well extended as an additional preventive against rain entering at the top of the walls. In such buildings it is also desirable to put brick in chunam round the windows and doors, to protect them.

Brickwork in chunam.—Brick in chunam mortar is superior to brickwork in clay in strength and durability due to the adhesion between the bricks and chunam. As a general rule, the brickwork of a building ought to be carried up uniformly, thus preventing the building having a tendency to sink more at one place than another. Bricks ought to be steeped in water before being used, or they are apt to extract much moisture from the chunam and thus tend to dry it up into dust. In building brickwork with chunam, it is always a good plan to keep the mortar floating on the brickwork, so that it enters every crevice.

Principles to be observed in construction of brickwork.—The following principles ought to be observed when building with bricks:—

(1) Reject all mis-shapen and unsound bricks.

(2) Place the beds of the courses as nearly perpendicular as possible to the pressure they will have to bear. Make the bricks in each course break joint with those of the courses above and below by overlapping to the extent of a quarter or one-half of the length of a brick.

(3) Clean the surface of each brick before using; wet it thoroughly before laying, in order that it may not absorb the moisture from the mortar too rapidly.

(4) Fill every joint thoroughly with mortar, taking care the joint is not more than one-quarter of an inch thick.

(5) Use no pieces of brick except where absolutely necessary in order to make a closure, that is, to finish the end or corner of a wall.

Bonding.—The greatest fault in Indian brickwork, and a most deplorable one, is want of '*bond*,' and to this want must be attributed most of the many disastrous falls of houses, huts, &c. Bonding is the arrangement of the bricks in

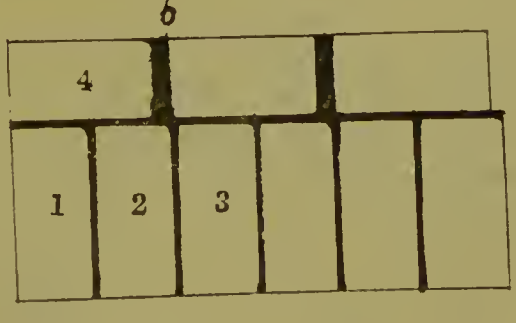
respect to one another, so that no joint in any course shall be in the same vertical line as any other joint in the course immediately above or below it. The object of bond is to preserve a transverse and a longitudinal tie between every portion of a structure, so that its stability should be practically independent of the mortar. The difficulty of maintaining proper bond when country bricks are used is due, as will be pointed out, to the omission to properly proportion the dimensions of the bricks.

Stretchers and headers.—Bricks laid lengthwise to a wall are called stretchers, those laid transversely are called headers. Each horizontal layer is called a course.

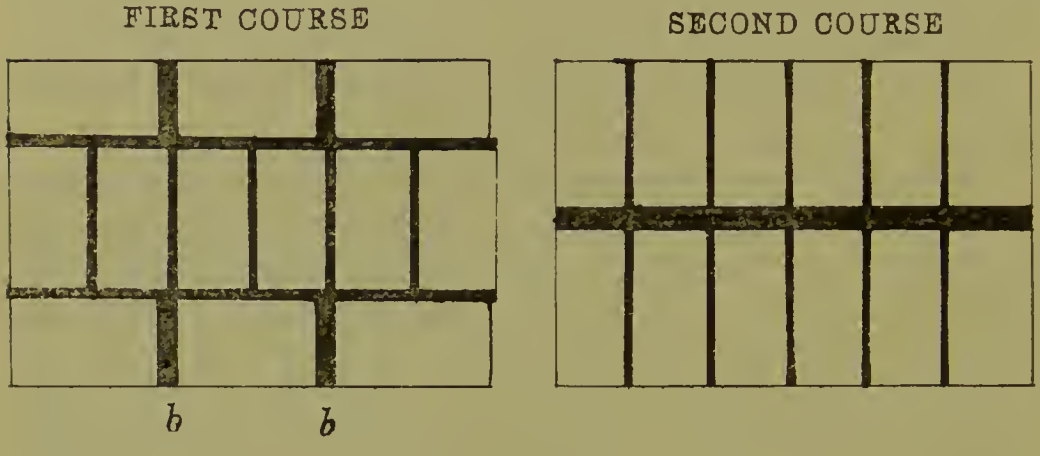
English bond.—English bond is obtained by laying entire courses of headers and of stretchers. Sometimes the courses are laid alternately, otherwise the header course is laid after two, three or four stretcher courses. In building this bond, it must be remembered that there are twice as many vertical joints in the header courses as in the stretcher and, therefore, in order to maintain the bond, the joints in the header courses must be made thinner than in the stretcher courses.

Flemish bond.—In flemish bond the headers and stretchers occur alternately in the same course; there are the same number of joints in each course.

Bonding cannot be expected when the bricks used are not properly proportioned and where in India walls are made so many feet and inches thick independently of the size of the brick used, it is generally impossible to get proper bond at all. If the size of bricks available were known beforehand, it would be easy to specify walls of so many bricks thick as is the practice in England, but even then with bricks out of proportion the bond will not be good. Take, for instance, a brick $8\frac{3}{4}'' \times 4\frac{1}{2}''$, and suppose the wall is to be $1\frac{1}{2}$ bricks thick, then proceed to lay the first course thus in order as marked 1, 2, 3, 4 :—



Now the length (4) is $8\frac{3}{4}''$, and the breadth of (1) is $4\frac{1}{2}''$. The bonding ought to proceed having all joints the same thickness, but, $8\frac{3}{4}''-4\frac{1}{2}''$ is $4\frac{1}{4}''$, but as the brick is $4\frac{1}{2}''$ broad when No. 2 brick is laid it extends beyond the end of No. 4 brick, and bond can be maintained only by making the joint at (*b*) much too large. The difficulties of effecting a good bond in a wall two bricks thick are still greater.



Four header bricks with three joints measure $4\frac{1}{2}'' + \frac{1}{4}'' + 4\frac{1}{2}'' + \frac{1}{4}'' + 4\frac{1}{2}'' + \frac{1}{4}'' + 4\frac{1}{2}'' + \frac{1}{4}'' = 19''$. Two stretcher bricks $= 2 \times 8\frac{3}{4}'' = 17\frac{1}{2}''$, thus leaving a joint of three-fourths of an inch between each two stretcher bricks; if the second course be compared with the first course, the first course $= 4\frac{1}{2} + \frac{1}{4} + 8\frac{3}{4} + \frac{1}{4} + 4\frac{1}{2} = 18\frac{1}{4}$, second course $= 8\frac{3}{4} + 8\frac{3}{4} = 17\frac{1}{2}$, thus necessitating down the middle of the wall a joint three-fourths of an inch thick.

With bricks not properly proportioned, it is therefore extremely difficult to do good work.

Proportions of bricks and mortar.—A cubic yard of country brickwork requires on an average about 5 cubic feet of mortar (the amount is dependent on the size of the brick); the number of bricks required for a cubic yard varies with their sizes—

Bricks $9'' \times 4\frac{1}{2}'' \times 3''$; 384 are required per cubic yard.
Do. $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{4}''$; 512 do. do.

The following is from a recent experiment:—

$$\frac{\text{Number of cubic feet of brickwork}}{308} = \text{Number of tons of cement required where sand to cement is in proportion of 3 to 1.}$$

$$\frac{\text{Number of cubic feet of brickwork}}{4} = \text{Number of cubic feet of sand do.}$$

$$\frac{\text{Number of cubic feet of brickwork}}{12} = \text{Number of cubic feet of cement do.}$$

Stone Masonry.

Classes of Masonry.—For engineering purposes, masonry may be classed as ashlar, coursed rubble, common rubble.

Ashlar.—Ashlar masonry consists of blocks cut to regular figures and built in courses of uniform depth. The breadth of each stone ought to be not less than one and-a-half times its height. The bed and side joints in this class of masonry are dressed to plane surfaces.

Coursed rubble consists of a series of horizontal courses not exceeding 1 foot in depth, each levelled before another course is put on, the joints are not necessarily vertical. One-fourth part of the face should be header stones, the spaces between which are filled in with stones of a height requiring one or two to the depth of a course. These headers should have a breadth one and-a-half times their depth, and their length should be three to five times their depth. The headers ought to be laid from alternate sides of the wall and bond with each other. Masonry of this kind requires about 5½ cubic feet of mortar per cubic yard of masonry.

Common rubble differs from coursed rubble in not being built in regular courses, the building must, however, be very carefully done to obtain strong work.

Beds and joints.—The face of a stone is its outer surface exposed to view, and is usually dressed; the back is the side opposite to the face; the bed of a stone is the surface parallel to the layers, but this term is also applied to the joints between the stone, the horizontal joints being called bed joints.

Foundations.

Preparation of foundation.—Before commencing to rear any structure, a strong unyielding foundation must be obtained or constructed. The examination of structures adjoining the site of a proposed building will be some guide to the depth of foundation necessary. As a rule, the surface soil must be cleared to a depth of 2 to 5 feet, and the foundations should always be broader on softer than on harder strata;

in very soft ground it is well to use concrete which forms an excellent bed for a foundation when carefully laid. The concrete bed must extend 6 inches on each side of the masonry resting on it, and it must not be less than 12 inches in thickness. In many instances, the foundation may have to be constructed on wells or inverted arches, but a certain amount of trained engineering skill is necessary in such cases, and such expedients therefore need not be further referred to.

Maximum pressure allowable.—The pressure of the foundations of a building on firm earth is usually between 2,500 lbs. and 3,500 lbs. to the square foot or from 17 to 24 lbs. to the square inch.

Breadth of foundation.—To prevent this weight being exceeded, and for other reasons in regard to stability, it is necessary to spread out the foundations; a good rule is to make the breadth of the base of the foundation courses one and one-half times the thickness of the wall when the soil is compact gravel and twice that thickness in sand or clay. For example, take a wall 18 inches thick and 30 feet high, then as brickwork weighs 112 lbs. per cubic foot, 1 foot of length of the wall would weigh 5,040 lbs., and this weight would press on an area $1 \times 1\frac{1}{2} = 1\frac{1}{2}$ square feet, so that the pressure would, in such case, be 3,360 lbs. which is slightly below the maximum limit. Nevertheless it is advisable to have footings, and the rule above quoted should be observed; it is always better to err on the safe side.

FIG. 2

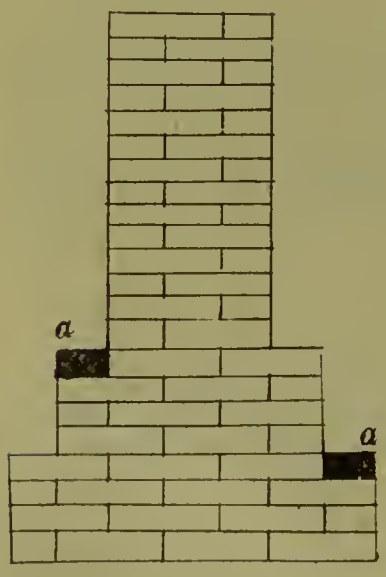
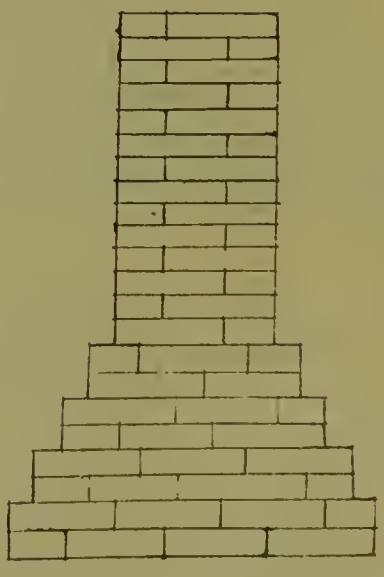


FIG. 1



Construction of foundation courses.—One point to be most carefully observed in constructing brick foundations is this, that the footings ought to be widened out only to the extent of $2\frac{1}{4}$ inches at a time. By referring to the above sketches, it will be seen that, while the bond in Fig. 1 is perfect, that in Fig. 2 is bad, the vertical joints occurring one above the other in alternate courses and the bricks *a* and *a* are of no use whatever. Taking each foundation with the same number of courses, and with the same bottom breadth, it will be found impossible to arrange the bricks satisfactorily with $4\frac{1}{2}''$ steppings. When constructing stone foundations the breadth of the steppings ought in no case to exceed one-fourth the average length of the header stones.

Sand foundations.—Instead of founding on concrete a good thick layer of sand may sometimes be used, but in such case the trench should also be filled with sand laid in layers one foot thick and well rammed.

Foundations in black-cotton soil.—Black-cotton soil, which is found in many parts of India, is a peculiar black earth which swells during the rains and shrinks during the dry weather. When it shrinks, deep cracks appear on the surface. Owing to these changes great care has to be exercised in building on black-cotton soil.

The following methods of founding buildings on the soil are recommended * :—

(1) When the soil is of small depth, excavate the whole of it over an area slightly larger than that of the proposed building which will then be founded on the harder sub-soil, the spaces round and between the walls being filled with sand or other sound material that may be available. In the case of small and cheap buildings, the black-cotton soil may be left within the walls, provided that there is a layer of at least 12 inches of good material between the floor and the top of the black-cotton soil.

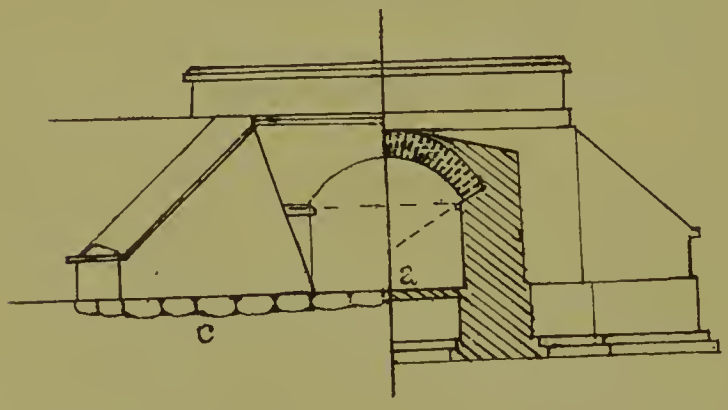
(2) When the depth of the black-cotton soil is such as to render the above method costly, the walls may be supported on jack arches springing from pillars sunk to the firm sub-soil. The pillars should be as few as possible, but they should be sufficiently strong to support the superstructure. The whole area about 2 feet wider on all sides than the building should be excavated down to the level of the springing of the arches

* *Vide* Minutes of Proceedings of the Institution of Civil Engineers, vol. cxiii.

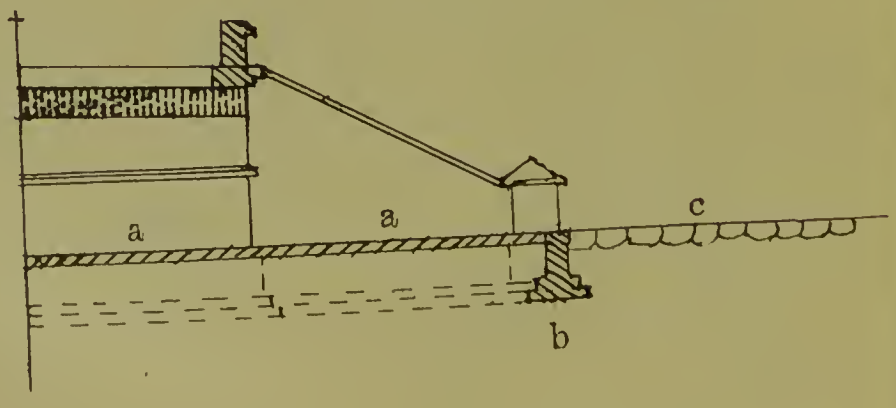
and filled with good materials as described before. The crown of the arches must be below ground level.

(3) When the depth of the soil is too great to admit of either of above methods being practised, the best method is to excavate an area little larger than the proposed building to a depth of, say, 10 feet and then fill in the excavated area with good material to a height of about 5 feet and build the foundations thereon. Another method is to use iron frame work to support the roof and make the walls simply screen walls. Old rails may be used for the uprights, set in concrete bases 3 feet or 4 feet deep and connected at the top with one another and with the roof trusses.

Protection of foundations against scour.—When constructing road culverts or other works exposed to scour, special means must be taken to protect their foundations from the heavy rushes of water which may have to pass through them, and this may be done by either an inverted arch or a flat floor between the abutments and by protecting them by curtain walls and at their down stream side by an apron. The following is a sketch of a road culvert constructed in that manner :—



a Flooring
b Curtain wall
c Apron



Thickness of walls of buildings.—The proper thickness for a wall of a building depends on the materials used and the weight to be supported. In England walls are sometimes made as little as half a brick in thickness, but in India such thin walls are not suitable; in buildings they would allow of heat passing through them and they would not exclude continuous damp. Walls in India are often unduly thick; if it be remembered that a pucca wall 1½ bricks thick will carry almost anything, there should be good reasons given before anything above that thickness is allowed. With inferior materials, of course, walls must be thicker. Taking 800 lbs. per inch as the crushing resistance of good masonry and 120 lbs. per cubic foot as its weight, a wall must be $\frac{800 \times 144}{120} = 960$ feet high before it will crush with its own weight; with a factor of 12, the result would be 80 feet.

In long walls, where there are no cross walls, buttresses should be introduced. Buttresses 8 to 12 feet apart and from one and one-half times the thickness of the wall are sufficient.

Prevention of Damp.—An important matter is to prevent damp rising from the ground through walls. The result of damp is that the materials of walls and buildings are saturated with nitrous salts, which rising above the ground evaporate their moisture and then crystallize. Their bulk is increased, they burst and disintegrate the brickwork and cause the plaster to crumble away. To prevent this, a damp proof course is necessary; this ought to be placed just above the plinth of the building or a foot or two above ground. For this purpose may be used asphalte or slate, a thick layer of strong cement concrete, sheet lead, &c. If cheapness is a consideration, a substitute may be found in laying the course in good bricks saturated with hot tar, the joints also being filled up with the same substance. A damp proof course also excludes white ants.

Brick on edge floors.—In Southern India floors for pucca buildings are ordinarily of one of these three descriptions, viz., brick on edge floors, square brick floors, or brick jelly floors. In all cases, however, it is necessary that the floor should be properly levelled and thoroughly consolidated by ramming the surface of the foundation, which should be at least 12 to 15 inches below the level of the surface of the intended floor; about 3 inches of sand should be laid, then two courses of bricks laid flat, the upper in mortar, then brick on edge, which ought to be carefully laid in straight lines with joints as fine as possible. After the bricks on edge have been

laid, the joints ought to be roughly filled with chunam and pointed.

Square brick floors.—Square brick floors are similarly constructed, these bricks taking the place of the bricks on edge. The paving bricks ought to be pointed with cement. A superior floor is obtained by the use of the oiled pressed tiles already spoken of.

Jelly floors.—In brick jelly floors, the brick jelly, which should be broken to a uniform size not larger than will pass through a one-inch ring, is thoroughly incorporated with mortar, well turned over, laid down on the top of the flat courses of bricks and then well beaten and rammed. This will bring the fine particles of mortar to the surface which ought to be rubbed smooth and polished, and a further skin of plaster may then be laid on.

Stone floors.—Stone may be used in place of square bricks, and in such case may be bedded directly on sand or on brick jelly mixed with chunam. The stones should be comparatively flat on their lower beds or they will cant. Cuddapah slabs make excellent floors.

Cemented floors.—Cemented floors are very durable and much cheaper than stone paving. They are useful in all sorts of buildings and structures. They can be made rough or smooth or even finely polished if necessary. The floor is prepared with concrete as in ordinary jelly floors, but all superfluous mortar is scraped away from the surface, leaving it rough. The concrete must then be allowed to set for some time say a month if possible but at least 15 days, otherwise cracks will appear in the cement coating. The surface should then be cleaned, damped and plastered with cement as already described. The floor should be kept covered with wet grass for ten days.

Asphalte, a bituminous limestone (the calcareous matter to bitumen being in the proportion of 83 to 17), is useful for damp proof courses, floors, terraced roofs, pavements, &c.; for roofs and floors, three-fourths inch thickness is sufficient, for pavements from 1½ to 2 inches. The preparation of asphalte consists in breaking it into small pieces of about ½ lb. each. These are heated in a boiler and the whole constantly stirred until liquid. Sand is then added in the proportion of two parts of sand to one of asphalte. The asphalte is laid hot and slips of wood or iron of the thickness of the proposed covering are placed so as to divide the space to be covered

into squares or rectangles. This prevents the asphalte spreading and ensures a level floor. The asphalte, as poured out, is evenly spread with a plasterer's float. Before the asphalte sets hard, fine sand should be sprinkled over it and well rubbed in.

Upper floors.—The descriptions above relate to lower floors and not to those of upper stories. These must be of wood or of terraced work over which stone, asphalte or cement is laid ; the manner of forming terraced floors is the same as that employed for terraced roofs, described a few paragraphs further on.

Stairs and steps.—Stairs are an assemblage of steps. A step consists of a tread and a riser combined ; the horizontal part is the tread, the vertical portion the riser. The tread of a step should be from 9 inches to 15 inches, the rise about $5\frac{1}{2}$ inches to 7 inches. If the height between two floors of a building be 14 feet, then there will be $\frac{14 \times 12}{6} = 28$ steps, 6 inches deep. A stair-case must, therefore, be so designed, that the length of the path of the centre equals the number of the risers less one multiplied by the breadth of the proposed tread ; suppose the tread in the above case to be one foot, then $(28-1) \times 1 = 27$ feet, which must be the least total length along the centre of the stair-case. The breadth of a stair-case ought not to be less than 4 feet 6 inches.

Roofs.—Indian roofs are of two kinds—flat or terraced and pent or inclined. The span of a roof is the distance between the walls or supports.

Inclined roofs.—In an inclined roof, the pitch is the height to which it rises in the centre above its supports. The pitch, in India, is usually one-third of the span ; it ought never to be less than one-sixth nor greater than one-half the span ; in the former case wind is apt to get under the tiles or thatch and rain to leak through the roof, while the latter presents a great surface to the wind and rain may be blown in through the tiles or thatch ; the roof covering is also apt to slip off.

Terraced roofs are nearly flat having only sufficient slope on their upper surface to carry off rain water. The following is the manner of constructing and repairing terraced roofs :—If the width of the room does not exceed 14 feet, the joists are laid across at intervals of 15 to 18 inches ; but if the width is greater than this, it is usual to divide the room into two or more portions by beams resting on the two walls which include the width ; the joists are laid at equal

intervals across these beams and at right angles to them. A course of bricks on edge in chunam is then laid diagonally over the joists, and when this has set, it is covered with a layer of brick jelly, 3 inches thick, which must be well beaten down. This should be allowed to remain for a few days in order to harden, and then three courses of flat tiles are laid, each tile in the two under courses being $6'' \times 3'' \times \frac{3}{4}''$, in the upper course $6'' \times 6'' \times \frac{1}{2}''$; these tiles are wetted before being laid, and each course breaks joint with that beneath it. The roof is finished off on the outside with three coats of plaster carefully applied and well rubbed to a polished surface. A parapet wall with a few openings in it to discharge rain water is built around the roof on the outer walls; a binding wall is built over each cross wall in the building to secure the ends of the joists.

Where the joists rest on the wall, the space between each pair is built up with masonry; when they are supported on beams, the spaces between the beams and terrace are closed with slips of wood half an inch thick. The thickness of an ordinary terrace roof is about 8 inches, thus made up: Brick on edge 3 inches, brick jelly 3 inches, beaten down to about 2 inches, flat tiles 2 inches, plaster 1 inch.

The weight of a terraced roof may be taken at 70 lbs. per square foot, and allowing 30 lbs. per square foot for accidental load, the pressure on each joist may be estimated at 100 lbs. for each square foot of roofing it supports.

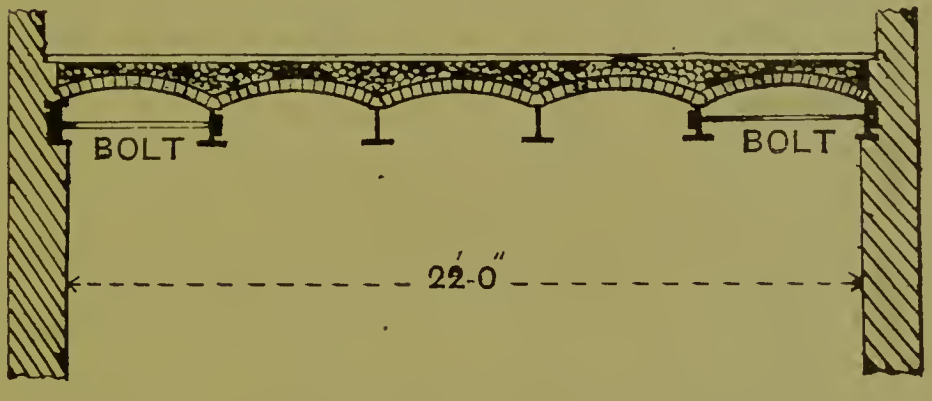
Rules for sizes of joists and beams.—A common rule for scantlings is to give, for every foot of unsupported length in a beam, one-half inch of breadth and three-quarters of an inch of depth.

A beam or joist should never be laid on its broad side, but always with its greatest dimension vertical. When a deep but narrow beam is used to span a large opening, it will be necessary to secure it, so that its greatest dimension shall always be truly vertical, as it would be greatly weakened by any turning of the beam in the middle of its length tending to throw it out of that position. Roof beams are now frequently constructed of rolled iron which is more durable than wood.

Arched roofing.—This is a fireproof construction of concrete or brick archwork in combination with iron. Owing to the absence in its construction of absorptive material like wood, its use is recommended for hospitals, &c. The roof may

be formed either of a single arch or a series of arches resting on rolled iron beams. Where a large area has to be covered, the latter method is preferable.

The following is an example of a roof covering a room 14′ × 22′:—



The end arches are tied, in the manner shown above, to relieve lateral thrust against the walls. The rise of the arch should not be less than 1 inch to a foot of span, nor need it be more than 1½ inches per foot of span. The best spacing for girders is from 4 to 5 feet. The arches are covered over with a depth of 3 inches concrete over crown. The proper dimensions for the rolled beams will be found in a table on a preceding page.

Repairs to terraced roofs.—Cracks in terraced roofs are generally caused either by the sagging of the beams or by the sinking of the supporting walls. Another cause of leakage is found in the careless manner in which the roofs are made; in some instances the only protection against leakage is the polished film of plaster on the exterior which is readily broken, especially when, as often happens, the roof is used as a promenade. To prevent leakage as much as possible, none but iron beams, or well-seasoned timber, of a proper scantling, should be used, and every course in the roof, whether brick on edge, jelly, or tiles, should be carefully laid. Cracks, when small, are repaired by filling them up with a composition that hardens on exposure or by covering them with a piece of

coarse cloth covered with tar. The compositions used to fill the cracks are—

1. Asphalte.
2. Tar and resin.
3. Linseed-oil (2 seers), resin (2 seers), pumice stone (1 seer).
4. Cotton (2 oz.), slaked lime (20 lbs.), linseed-oil (10 lbs.).

The resin and pumice stone must be ground to a fine powder, and the cotton cut up very fine. The ingredients should be thoroughly mixed, and (4) should be ground to the consistency of paste. The composition is poured into the crack, and allowed to extend a few inches on each side of it. A simple and effective plan is to prepare milk of lime and slowly pour it into a crack. The water will evaporate and the crack be filled with lime. Sometimes a row of pan-tiles is used, the convex side uppermost, to cover the crack and coated over with plaster or tar. When the roof is cracked in many places, the best and cheapest way to repair it is to cover the outer surface with a thin coat of asphalte. The thickness of the layer need not exceed a quarter inch, and more sand than is used for a floor may be advantageously mixed with the asphalte. The additional weight per square foot will not exceed 2 lbs.

Bengal roofs.—The most simple form of sloping roof is the Bengal terraced roof. This roof, which is often used for covering verandahs, is thus constructed; rafters are made to enter the main wall of the building about 9 inches, and slightly sloping downwards, are fixed at their opposite ends to a wall and wall plate or spiked to a bressummer supported on verandah pillars; the rafters are placed at equal intervals of 12 or 18 inches from centre to centre. Reepers or laths 6 inches apart from centre to centre, two inches wide and half an inch thick are nailed to the upper surface of the rafters at right angles to their direction; on these a course of flat tiles ($6'' \times 3\frac{1}{2}'' \times \frac{3}{4}''$) is laid, with mortar between the joints. The roof is then completed in various ways, one being to lay two courses of flat tiles in mortar over this course and finish off with two or three coats of plaster well rubbed down; the top course may be of thin tiles (half inch thick). Another method is to place a layer of fine jelly $1\frac{1}{2}$ inches thick over the first course of tiles, then a second course of tiles, and lastly two or three coats of plaster well rubbed down. The tiles should be wetted before being laid; those next the wall should enter it a few inches to prevent leakage at the junction of the roof and wall.

Size of timber in Bengal roofs.—A common rule is to give to the rafter one-quarter inch of breadth and one-half inch in depth for every foot clear in the width of the span and to the bressummers one-half inch of breadth and three-quarters of an inch in depth for every foot length in the clear. The rafters should project 12 or 18 inches beyond the pillars or lower wall.* The slope to be given to these roofs need not exceed 1 in 4; in general 1 in 6 will be found sufficient. Cracks in these roofs are repaired in the same manner as those in a flat terrace roof.

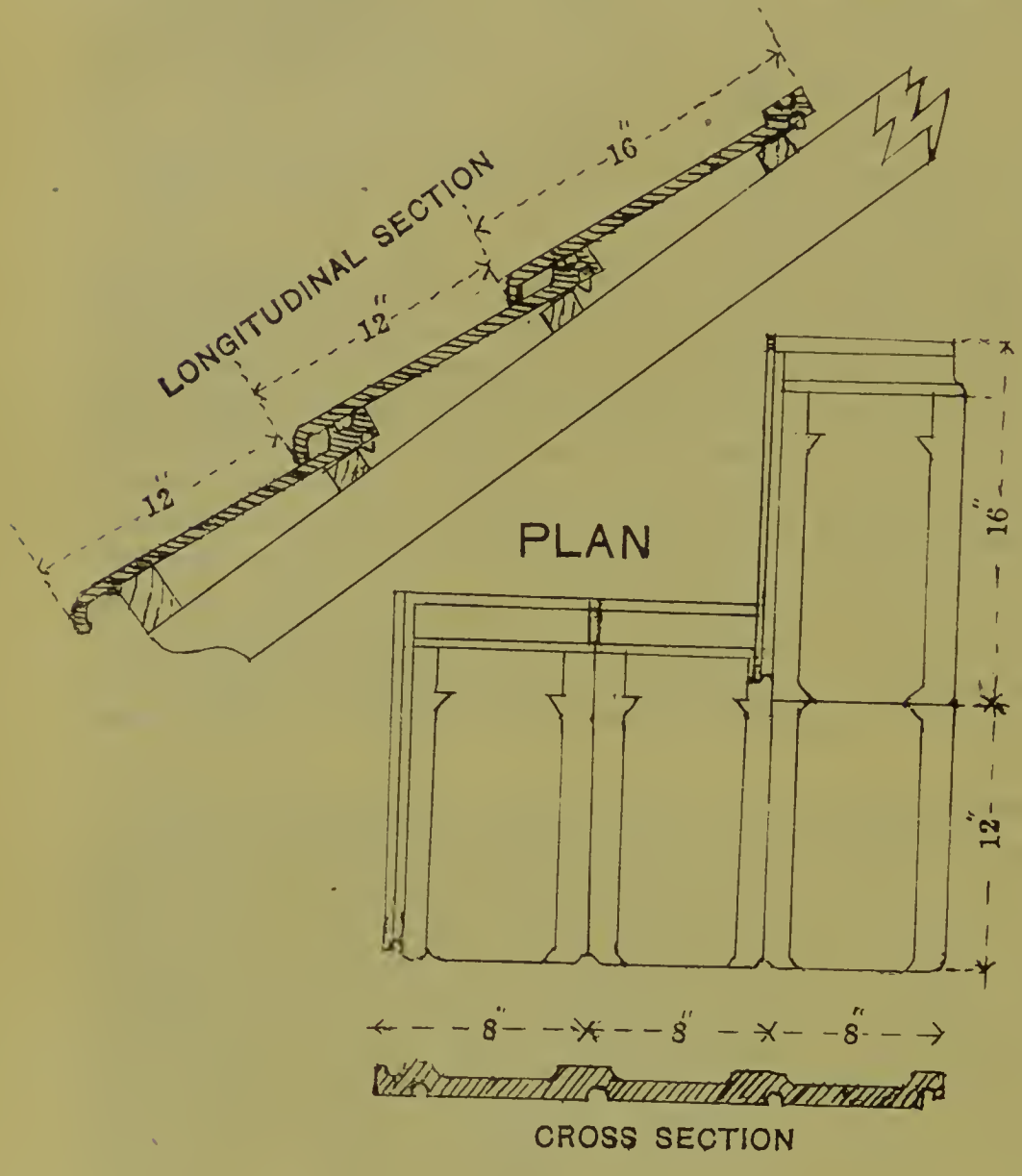
Pent roofs.—For rectangular buildings the roof may consist of two planes equally inclined terminating in the ridge half way between the two supports or walls. The roofs may be continued to the ends of the building, and the walls built up in the form of gables, or planes equally inclined, may start from these end walls meeting the ridge, in which case the roof is called a hipped roof, while the former is known as a gabled roof. The roofs are supported by frames of various description known as trusses, the different parts of which are proportioned from a consideration of the strains affecting them; it is beyond the scope of this work to go into the theory of their construction. The trusses may be formed of either wood or iron.

Tiled roofs.—In ordinary tiled roofs the first course consists of flat tiles 6″ × 6″ × ½″ pointed with mortar and laid over the reepers. Pan-tiles are then laid over them in rows with the concave sides uppermost, touching each other from top to bottom. These tiles are smaller at one end than the other so as to overlap, which they should do to the extent of not less than one-quarter their length. A second course is then laid convex side uppermost overlapping each other and so as to cover the intervals between the first course. The ridges and hips, if any, are covered by tiles of triangular section specially made; these are laid in mortar. The ridges may also be covered with plaster 6 to 12 inches in width and similar bands of plaster may be laid down the sides of the roof, the strips being from 2 to 3 feet apart; these are called chunam borders.

Repairs to tiled roofs.—When an ordinary tiled roof leaks, unless it is only in a very small portion which can be repaired by replacing one or two tiles without interfering with the others, it is better to remove all the tiles. Shifting a portion only, of the tiles causes more leaks owing to the lower

* This forms the *eaves*, and carries rain water clear of the walls.

tiles of the sound portions getting broken during the process. An estimate for repairs ought to provide for shifting tiles, new chunam borders, one-fourth pan-tiles, and one-third flat tiles.



Mangalore tiled roofs.—The advantages claimed for Mangalore tiles are (1) appearance, (2) comparatively small weight, (3) adaptability to roofs of flat slopes, (4) simplicity and ease of arrangement, (5) immunity from annual repairs, (6) facility of repairs when necessary, and (7) economy.

Mangalore tiles are interlocking. They are large and well-made tiles. Their extreme dimensions are 1 foot $4\frac{1}{2}$ inches in length and 9 inches in width. Each has a groove at the side into which a corresponding projection on the next tile fits. At the top each has a groove corresponding with a projection at the bottom of the tile immediately above it.

In addition to these grooves and projections, the free ends of the tiles butt against two projections or tenons on the top of the tiles just below them. The tiles rest on reepers placed 12 inches from centre to centre, and are prevented from sliding down by two nibs on their under side by which the tiles are hung from the reepers. The lap at the top is 4½ inches, while the lateral lap is only one inch. As the tiles fit into one another perfectly and form water-tight joints, the above lap is quite sufficient to prevent the rain driving underneath them. The available area of each tile for roof covering is 1 foot by 8 inches. These tiles will lie very closely, and the weight of each is such that it is almost impossible for the wind to strip them. The body of the tiles is only three-eighths of an inch thick, but the projections at the sides and ends impart to them a great deal of strength. To add to their strength still further they have ribs at the two sides, of which one has the groove above named, and the other has spoon-shaded indentations, which reduce the weight of the tiles without interfering with the strength of the ribs.

(1) *Appearance.*—In appearance and effect Mangalore tiles possess an acknowledged superiority over the ordinary roof coverings of this country. Their even surfaces and symmetry of arrangement contrast very favourably with the rugged, uneven, and crooked arrangement of the pan-tiles. There is a practice in some places of coating the top or exposed surface of these tiles with tar. The object of coating the tiles with tar is (1) to make them less impervious to rain water; (2) to prevent the growth of vegetation on their surface; (3) to protect them from the action of weather and abrasion caused by the driving of rain. These objects can be gained by other means which, with a little more cost, will retain the beauty of the roof. A good effect can be produced by painting the tiles a brown, grey, or bathstone colour with silicate paints. Neither tarring nor painting is however absolutely necessary to keep the tiles in a good state of preservation. There are roofs existing which were erected some 20 years ago on the first introduction of these tiles. Time and weather seem to have made no impression on their surface except to give them a weathered appearance.

(2) *Weight.*—Each Mangalore tile weighs on an average 5½ lbs.; 150 tiles go to make a square of roofing and weigh about 8 cwt. The same area of roofing with ordinary tiles weighs about 18 cwt. exclusive of the chunam borders. Mangalore tiles are by far the lightest of all those yet introduced in India.

(3) *Adaptability to roofs of flat slopes.*—Mangalore tiles can be laid at a much flatter slope than ordinary tiles. In Mangalore, where the annual rainfall is about 150 inches, almost the whole of which falls in about two or three months, the pitches of the roofs vary from 33° to 26°. In Madras where the average of rainfall for the last 70 years is 48·71 inches and distributed over a longer period, roofs can be laid at a much flatter slope than 26° when necessary. This feature of the tiles coupled with their lightness fits them excellently for store sheds, warehouses, factories, &c., especially for the last class of buildings; where there is smoke such roofs are preferable to corrugated iron, as the latter deteriorates very rapidly in such situations.

(4) *Simplicity and ease of arrangement.*—Mangalore tiles can be laid by ordinary unskilled workmen.

(5) *Immunity from annual repairs.*—The annual repairs to the ordinary roofs by shifting and relaying the tiles, which is a constantly recurring item of expenditure, disappears when a roof is covered with Mangalore tiles. A roof once properly finished will not require to be touched.

(6) *Facility of repairs when necessary.*—Any leaks by breakage in the case of Mangalore tiles can be readily detected and the evil remedied by replacing the broken tiles without disturbing any of those adjoining, unlike an ordinary roof which requires shifting all round when a roof once commences to leak.

(7) *Economy.*—With these advantages, the adoption or non-adoption of Mangalore tiles resolves itself into merely a question of cost. Most builders in Madras have been deterred from using these tiles on account of their cost; this is only apparent and not real if account is taken of the quantity of timber necessary for the construction of such roofs. With similar spans and the same area to be covered, a roof of Mangalore tiles requires much less timber than one covered with ordinary tiles. A Mangalore tiled roof weighs less than an ordinary tiled roof. Hence less timber is requisite in the construction of Mangalore tiled roofs on account of the less superincumbent weight. It appears that, in the Bombay Public Works Department, it is an usual practice to assume the quantity of timber in a roof covered with Mangalore tiles as being only 66 per cent. that of an ordinary roof. The reduction in timber is effected by placing the rafters and trusses at a greater distance from each other than in the case of

ordinary tiles, the scantlings of the various parts of the roof still remaining the same. For instance, rafters may be placed 2 feet 3 inches apart instead of 1 foot 6 inches apart as is usual with common roofs. Trusses are also placed further distant, and it is not unusual to have them 15 feet apart.

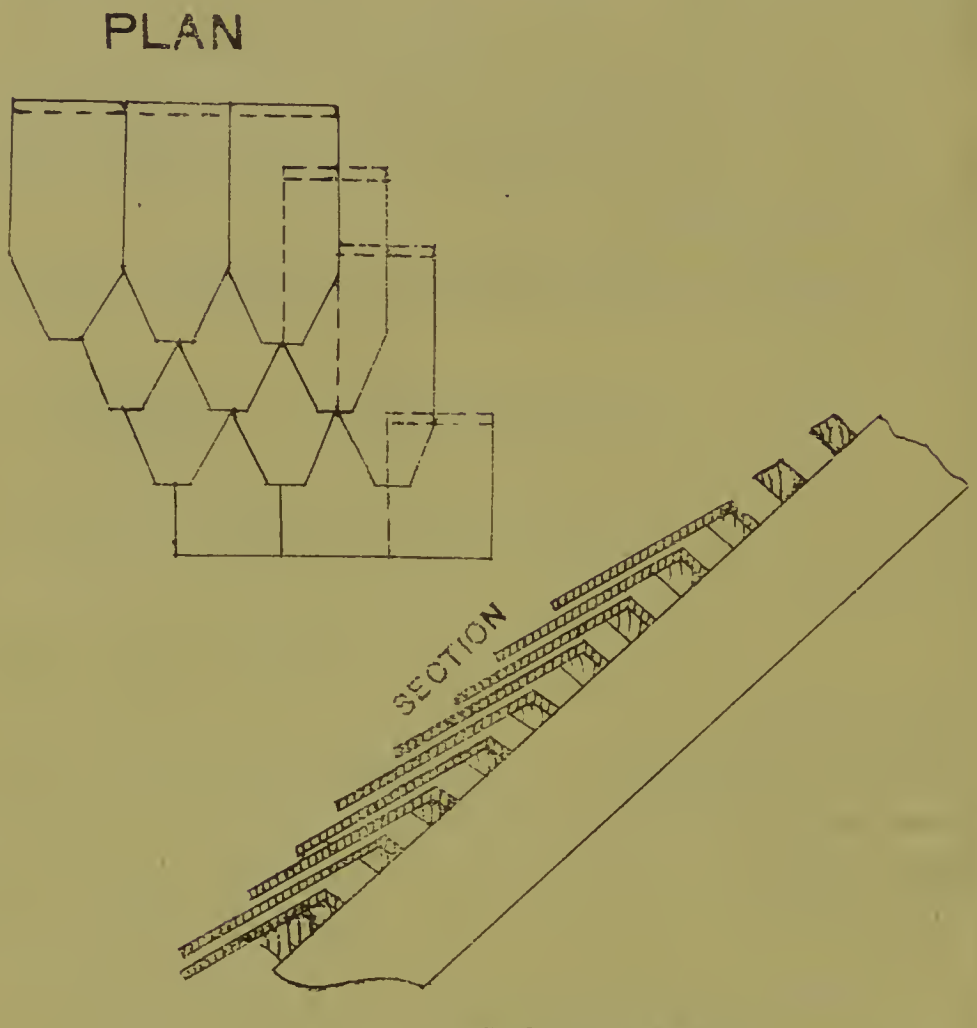
By detailed calculations, it has been proved that the cost of a square of roof complete, including tiles, timber, &c., is Rs. 37 when Mangalore tiles are used, and Rs. 39 when country tiles are used.

The results of such calculations are embodied in the following table:—

Description of roof.	Weight in cwts. per square.			Cost in rupees per square.		
	Wood-work.	Roofing.	Total.	Wood-work.	Roofing.	Total.
	CWT.	CWT.	CWT.	RS.	RS.	RS.
School of Arts tiles laid with chunam ...	5	17	22	37	35	72
School of Arts tiles laid without chunam ...	5	15	20	37	25	62
Flat and pan-tiles ...	4	18	22	30	9	39
Mangalore tiles ...	3	8	11	21	16	37

Madras School of Arts tiles.—Mr. R. F. Chisholm, F.R.I.B.A., late Consulting Architect to Government of Madras, covered some of his buildings with a simple, yet effective, pattern of tiles of local manufacture. The tiles have plain flat surfaces 10 inches long and 4½ inches wide, with a thickness of half an inch. The lower ends are V-shaped, 3 inches deep. The upper ends are turned down three-fourths of an inch, so as to form a lip by which the tiles are secured to the reepers. As there is no lateral lap, it is necessary that each course should overlap the next but one below it. For this purpose the reepers are placed 3 inches from centre to centre, and the length of the tiles being 10 inches, there are three thicknesses of tiles at every point of the roof. Each tile covers the vertical joint made by the two tiles below; thus the exposed portion of each tile is a diagonally placed square. With a high pitch which is a necessary feature of roofs

covered with these tiles, the effect is picturesque; but they make a heavy and somewhat expensive roof.



Scale 1 Inch = 1 Foot

Each course of tiles is laid over the one below with a thin layer of mortar. The roof mainly depends upon this cementing material for water-tightness, and consequently great care is necessary in laying the tiles, so as to secure a perfectly water-tight roof. Repairs are also difficult. A broken tile cannot be replaced unless some more of the contiguous tiles are also removed. The fact of their being jointed and bedded in mortar makes this operation difficult.

Weight.—One thousand and eighty of these tiles go to make a square of roofing and weigh 15 cwt. With the weight of chunam used for laying the tiles, the aggregate weight of the roof covering exceeds 17 cwt.; thus the weight of this roofing is almost as much as that of the one covered with flat and pan tiles.

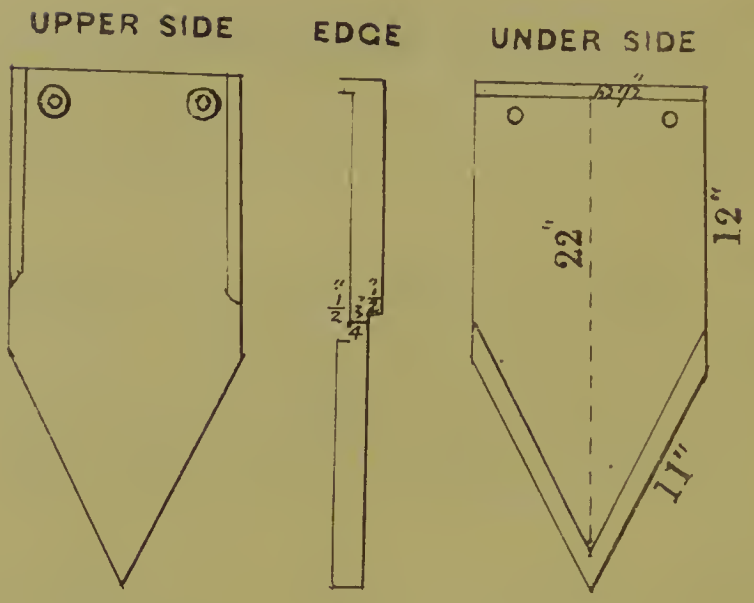
Cost.—The cost of these tiles is Rs. 17 per thousand at the kilns. The cost per square of roofing, including tiles, chunam and labour for fixing, is Rs. 35. This is expensive and places such roofing beyond the reach of ordinary builders. The same area of roofing with flat and pan tiles would cost Rs. 9.

Sialkot tiles.—The late Major-General Harley-Maxwell, R.E., brought to the author's notice a tile he used in the construction of Christ's Church, Sialkot. The diagram on the next page shows the plan, section and arrangement of these tiles. Their average weight is 6·5 lbs. each and to cover 10 square feet requires 22 tiles. Their cost is not ascertained, but they cannot be more expensive than the Mangalore tiles.

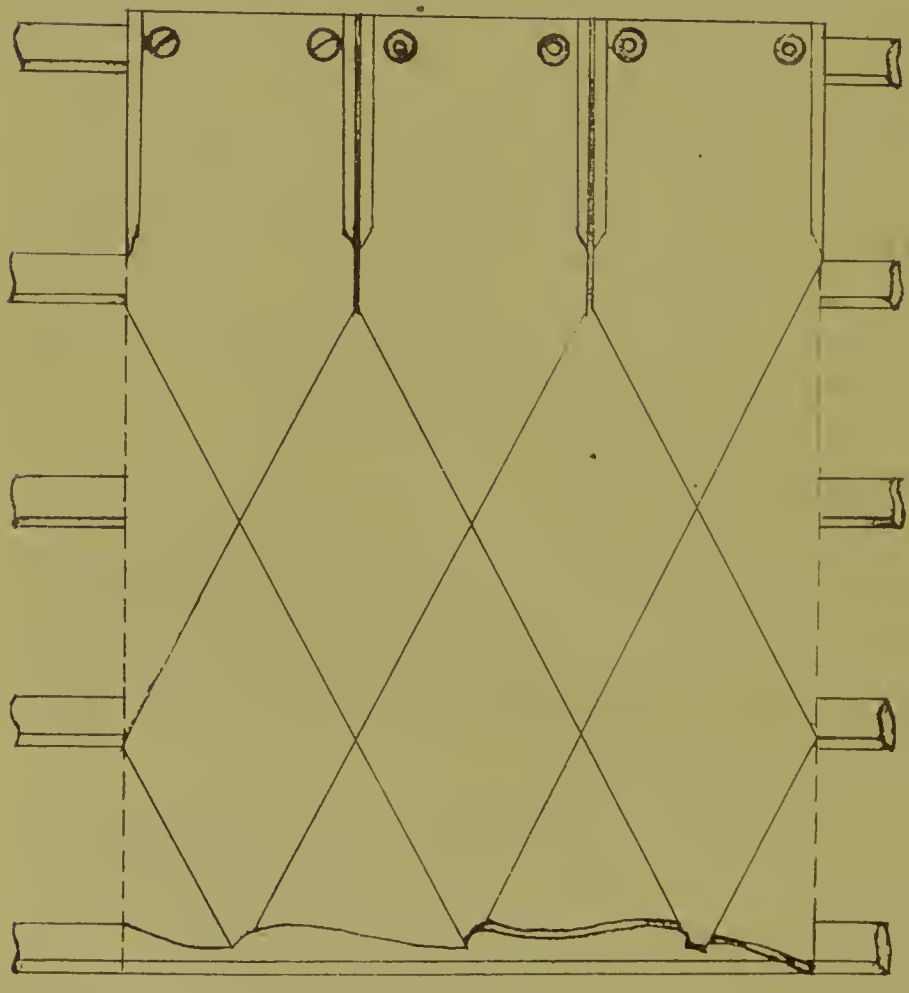
Thatched roofs may be formed by couples made of palmyra or bamboo crossed by reepers. Reeds, jungle grass, straw, cocoanut and palmyra leaves are used for thatching. A thatched roof of jungle grass makes a cool covering and has a neat appearance; it is better than straw, which should be renewed annually. Both descriptions of roof ought to be covered with light bamboo trellis-work to protect them against the effects of the wind. The rise to the ridge of these roofs ought to be not less than one-half the span. The thatch ought to be from 9 inches to 12 inches thick; in construction the bundles are fastened to the reepers which may be of palmyra or bamboo beginning from the eaves upwards, and the bundles so laid that they overlap one another well. The ridge is bound with a roll of grass laid horizontally.

Corrugated iron roofs are found useful in places where there is heavy rainfall and are sometimes interposed in inclined roofs between the tiles and the supporting framing. As they are good conductors of heat and sound, they must be covered with tiles, &c., when they form portions of roofs of dwelling houses, but without any covering they form admirable roofs for workshops, sheds, &c., through which there is a good current of air.

Galvanized corrugated iron sheets suitable for roofing are of 18, 20, 22 or 24 B.W.G. The 20 B.W.G. is the most useful gauge for roofing. The sheets are laid on the roof with laps of 6 inches at the ends and with two corrugations at the sides. The holes for the rivets must be drilled and not punched from the inside to the outside at a distance of 9 inches apart on the sides and on every second corrugation at the ends. The sheets must be fastened together by galvanized rivets and lead washers and fastened to the purlins at



ARRANGEMENT OF ROOF



SIALKOT TILES

distances of 5 feet by patent fasteners or galvanized iron screws and washers or bolts. The rivets must pass through the ridges and not through the valleys.

The following table gives the weight of corrugated iron roofing per square including lappage :—

Gauge.	Weight. LBS.
18 B.W.G.	236
20 do.	190
22 do.	150
24 do.	130

Brick arches.—In the construction of a brick arch, it is necessary that all the bricks in the arch radiate properly, that is, the joints must be in prolongation of the radius of curvature. When there is more than one ring of brickwork in an arch, it is better (and such is the practice in England in regard to arches up to 40 feet span) that no attempt be made to bond the various rings together; as in this country the mortar often sets quite as hard as the bricks, the former plan has nothing to recommend it as the bonding is as good as if the bricks themselves passed from one ring into another, nor is unequal settlement more likely in the one plan than the other even considering that there are more joints in the outer than the inner rings. All the bricks ought to be laid as stretchers.

The proper depth for the crown of an arch may be found by the following formula :—

$$D = \sqrt{(\cdot 12 \times \text{radius at the crown})}$$

Suppose the radius of curvature of the arch is 10 feet, then $D = \sqrt{(\cdot 12 \times 10)} = \sqrt{1 \cdot 2} = 1 \cdot 1$ feet.

Take again a semi-circular arch over a door, say, 4 feet wide, then—

$$D = \sqrt{(\cdot 12 \times 2)} = \sqrt{\cdot 24} = 6 \text{ inches nearly.}$$

These would be the dimensions below which the arches ought not to be constructed, and in the former case three rings would be used or $3 \times 4\frac{1}{2}'' + \frac{1}{2} = 14$ inches, and in the latter two rings or $2 \times 4\frac{1}{2}'' + \frac{1}{4} = 9\frac{1}{4}$ inches.

Flat brick arches.—For flat arches over windows and doors, the joints ought to radiate to the point where a prolongation of the lines of the skew-backs meet. The bricks require to be rubbed to the proper shape.

Cambered arches.—An arch, with a rise of a few inches at the centre, called a cambered arch, is very often employed

over doors and windows. The rise should be as many inches as there are feet in the span of the arch. The skew-backs should form an angle of 60° with the horizontal line.

Stone arches.—In stone arches, the arch stones, called voussoirs, are cut to a wedge-shape, the angle between two bed joints of the stone being dependent on the radius of curvature of the arch. Stone arches are usually built with voussoirs, the depth of which is equal to the depth of the arch ring and not in one or two courses as in brickwork.

Arch centres.—It is not necessary to describe the method of forming centering for arches, as all centering for large arches ought to be constructed under professional supervision; as centering for small arches is usually constructed of brick and mud without any arrangements for gradually lowering the centering, a native maistry is perfectly well able to design and construct it.

Doors and windows.—Doors and windows are of the following classes:—

(1) Batten, (2) Panelled, (3) Panelled and venetianed, (4) Venetianed and (5) Glazed. The terms are self-descriptive. Doors and windows are usually made of teak or of some durable wood. Doors should not be less than $6\frac{1}{2}$ feet in clear height and 3 feet in clear breadth. Where the sill of the door frame is liable to be injured by heavy traffic as in warehouses, godowns, &c., it is sometimes omitted and in such case the uprights of the frame are tenoned into a sill stone.

Windows are usually placed with their sills about 2 feet above floor and their tops level with that of the doors.

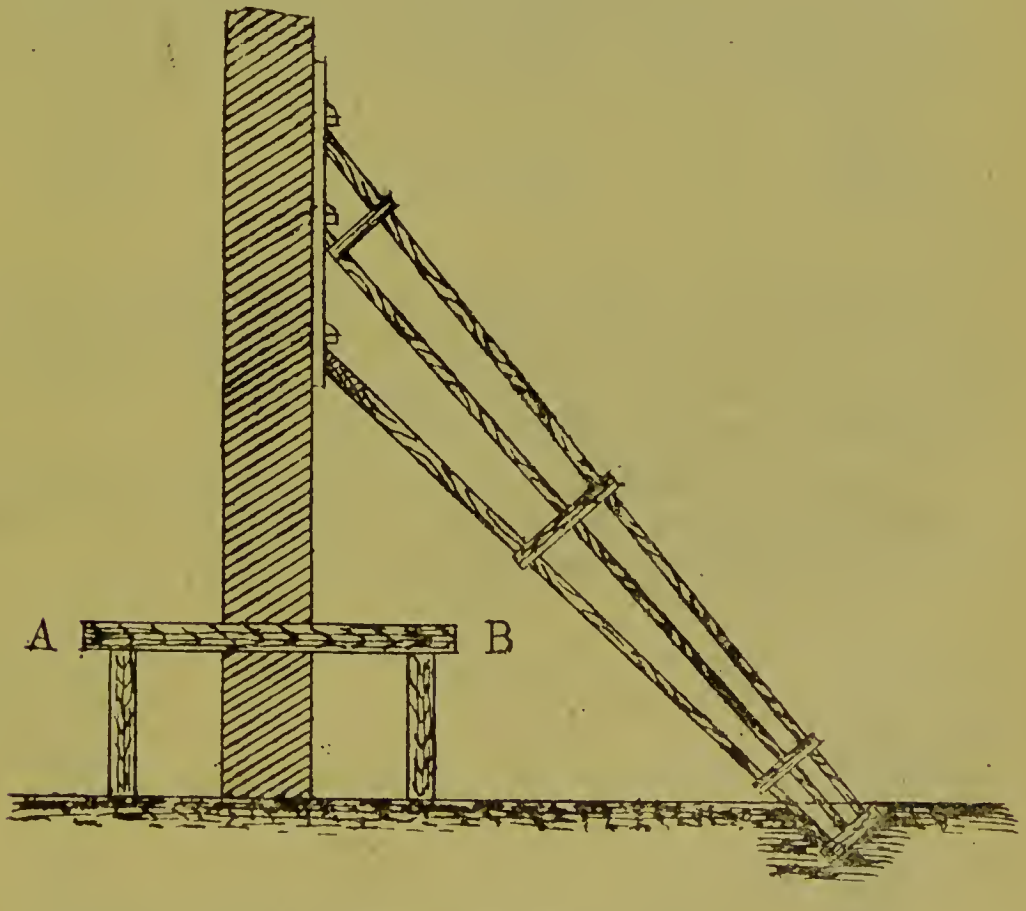
The parts of the door frames hidden by masonry must be coated with boiling coal tar before the frames are fixed.

The following table gives the dimensions of the various parts of doors and windows of the more usual sizes:—

—	Doors.			Windows.	
	5 × 8.	4 × 8.	4 × 7.	4 × 6.	$3\frac{1}{2}$ × 5.
Frames ...	5″ × 4″	5″ × 4″	5″ × 4″	4″ × 3″	4″ × 3″
Stiles ...	4″ × $1\frac{1}{2}$″	4″ × $1\frac{1}{2}$″	4″ × $1\frac{1}{2}$″	3″ × $1\frac{1}{4}$″	3″ × $1\frac{1}{4}$″
Top rail ...	4″ × $1\frac{1}{2}$″	4″ × $1\frac{1}{2}$″	4″ × $1\frac{1}{2}$″	3″ × $1\frac{1}{4}$″	3″ × $1\frac{1}{4}$″
Centre rail...	6″ × $1\frac{1}{2}$″	6″ × $1\frac{1}{2}$″	6″ × $1\frac{1}{2}$″	5″ × $1\frac{1}{4}$″	5″ × $1\frac{1}{4}$″
Bottom rail.	5″ × $1\frac{1}{2}$″	5″ × $1\frac{1}{2}$″	5″ × $1\frac{1}{2}$″	4″ × $1\frac{1}{4}$″	4″ × $1\frac{1}{4}$″
Panel ...	$1\frac{1}{4}$″	$1\frac{1}{4}$″	$1\frac{1}{4}$″	1″	1″
Venetians ...	6″ × $\frac{5}{8}$″	6″ × $\frac{1}{2}$″	6″ × $\frac{1}{2}$″	5″ × $\frac{1}{2}$″	5″ × $\frac{1}{2}$″
Sash bar ...	1″ × $1\frac{1}{2}$″	1″ × $1\frac{1}{2}$″	1″ × $1\frac{1}{4}$″	1″ × $1\frac{1}{4}$″	1″ × $1\frac{1}{4}$″

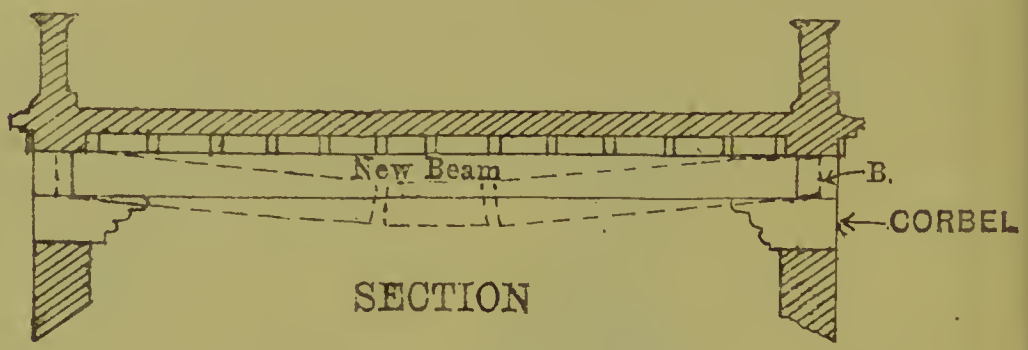
Repairs to buildings.—In repairing or extending an old wall, the junction between the old and the new work ought to be cut into the form of steps. The old work ought to be scraped clear of chunam and kept moist until the new work is finished.

Underpinning walls is performed by cutting holes through the sound portion of the wall above the portion to be renewed, and passing through it timbers of sufficient size, so that when supported at either end, they will be strong enough to bear the superincumbent structure, thus :—



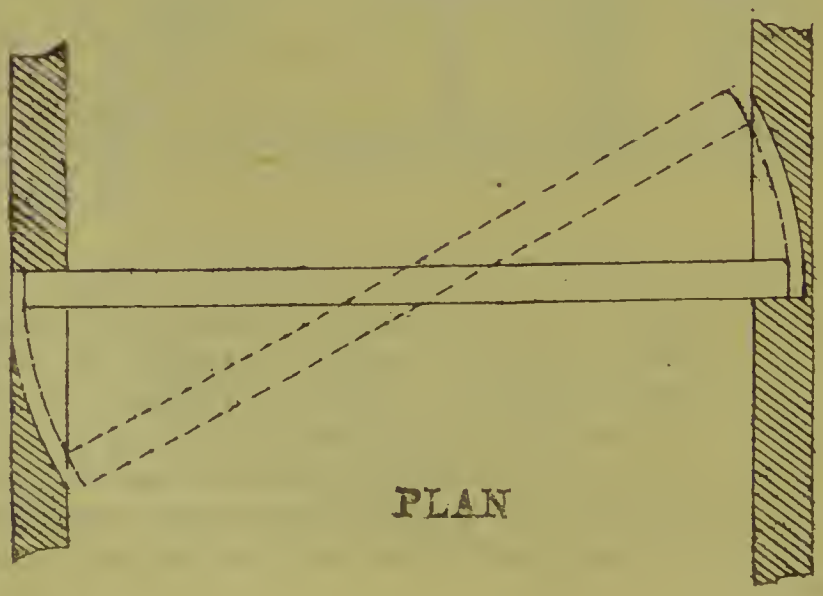
The timber (A B) passed through the wall is called a needle; the vertical pieces or struts are then placed under the needle and must be carefully wedged up tight, but not too tight. The struts ought to be as near the work as convenience will permit. These needles and struts ought not to be more than 8 feet apart, and in heavy structures at a much less distance. When the new foundation has been completed, it ought to be allowed to set a few days before the beams are removed.

Replacing beams.—In replacing beams the first thing to be done is to take off all superincumbent weight by strutting up, with supports bearing on planks, any rafters, joists, &c. The masonry at the end of the beam is then cut away and the beam passed out through the wall, and by a similar process a new beam is inserted. In many instances probably it may be necessary after relieving the beam to cut it, as space may not allow of its being passed out whole. The new beam will then have to be shorter, and where this is so, portions of the old beam may be used as corbels thus :—



The new beam, when being placed in position, will have to be thrust back at one end, as far as (say) B, and then, when the other end has been inserted, drawn forward until its centre is over the centre of the span.

Another method is to cut away the walls on either side of an old beam, so that when revolved on its axis or round one end it will clear the wall thus, in plan :—

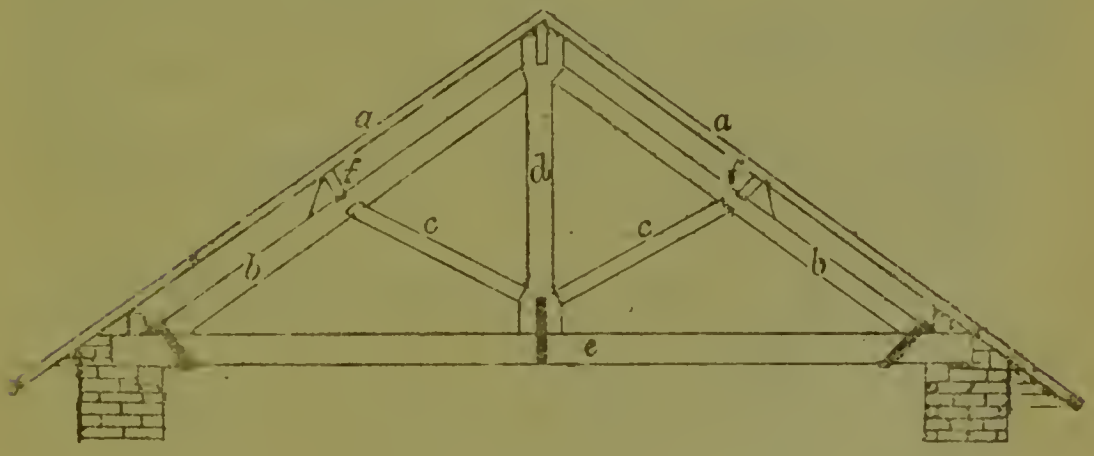


In such case the supporting strutting must be kept far enough off to allow this revolution to take place.

Insertion of arches in walls.—The position of the arch, its extrados and intrados, ought to be carefully marked; the portions of the old masonry next the springing of the arch should then be cut out and a portion of the arch built in, and so on, until the arch is completed up to the crown. Care should be taken to cut away the masonry exactly to the shape and size of the arch, so that no movement can take place after the arch has been put in.

Several tables compiled by General Sankey, when Assistant Chief Engineer, Mysore Public Works Department, showing the proper sizes of timber to be used in roof construction will be found on pages 216 to 221.

The following diagram shows the various portions of a trussed roof referred to in table No. V;—



a a. Common Rafters
b b. Principal Rafters
c c. Struts
d. King post
e. Tie beam
f f. Purlins

TABLE I.

Scantlings of Joists for Terraced Roofs.

Distance between points of support.	Total length including bearings.	Decimal Division.						Duodecimal Division.					
		Joists 1·25 feet apart from centre to centre.			Joists 1·50 feet apart from centre to centre.			Joists 15 inches apart from centre to centre.			Joists 18 inches apart from centre to centre.		
		B.	D.	Contents.	B.	D.	Contents.	B.	D.	Contents.	B.	D.	Contents.
FEET.	FEET.	FEET.	FEET.	C. FEET.	FEET.	FEET.	C. FEET.	INCHES.	INCHES.	C. FEET.	INCHES.	INCHES.	C. FEET.
8	9½	·25	·38	·90	·25	·42	1·00	3	4½	·89	3	5	·33
9	10½	·25	·43	1·13	·25	·47	1·23	3	5¼	1·15	3	5¾	1·26
10	11½	·25	·48	1·38	·25	·53	1·52	3	5¾	1·38	3	6½	1·56
11	12½	·25	·52	1·63	·25	·58	1·81	3	6¼	1·63	3	7	1·82
12	13½	·25	·57	1·92	·25	·63	2·04	3	6¾	1·92	3	7½	2·11
13	14½	·25	·62	2·25	·25	·68	2·47	3	7½	2·27	3	8¼	2·49
14	15½	·25	·67	2·60	·25	·74	2·87	3	8	2·58	3	9	2·91
15	16½	·25	·71	2·98	·25	·79	3·26	3	8½	2·92	3	9½	3·26
16	17½	·25	·76	3·33	·25	·84	3·68	3	9	3·28	3	10	3·65
17	19	·35	·68	4·52	·35	·76	5·05	4	8½	4·49	4	9¼	4·88
18	20	·35	·72	5·04	·35	·80	5·60	4	9	5·00	4	9¾	5·42
19	21	·35	·76	5·59	·35	·84	6·17	4	9½	5·54	4	10½	6·13
20	22	·35	·80	6·16	·35	·89	6·85	4	10	6·11	4	11	6·72
21	23	·35	·84	6·76	·35	·93	7·49	4	10½	6·79	4	11½	7·35
22	24	·35	·88	7·39	·35	·98	8·23	4	11	7·33	4	12	8·00
23	25	·35	·92	8·05	·35	1·02	8·93	4	11½	7·99	4	12½	8·68
24	26	·35	·96	8·74	·35	1·07	9·74	4	12	8·67	4	13	9·39

Table II.

Scantlings of Girders or Beams for Terraced Roofs.

Distance between points of support.	Total length including bearings.	Decimal Division.						Duodecimal Division.						Remarks.
		Breadth.	Depth.	Distance of girders from centre to centre.				Breadth.	Depth.	Distance of girders from centre to centre.				
				6 feet.	8 feet.	10 feet.	12 feet.			6 feet.	8 feet.	10 feet.	12 feet.	
FEET.	FEET.	FEET.	FEET.	CONTENTS IN CUBIC FEET.				INCHES.	INCHES	CONTENTS IN CUBIC FEET.				
16	18½	One-twelfth of distance of girders from centre to centre.	1·15	10·64	14·19	17·74	21·29	One inch per foot of distance of girders from centre to centre.	13¾	10·60	14·18	13·17	21·20	It is rarely worth while to use girders for spans less than 18 feet. The most convenient distance from centre to centre of girders will usually be from 10 to 12 feet.
17	19½		1·22	11·98	15·86	19·83	23·79		14¾	11·98	15·98	19·98	23·97	
18	20½		1·30	13·33	17·77	22·21	26·55		15½	13·24	17·65	22·57	26·48	
19	21½		1·37	14·72	19·63	24·55	29·46		16½	14·78	19·71	24·64	29·56	
20	22½		1·44	16·20	21·60	27·00	32·40		17¼	16·17	21·53	26·94	32·34	
21	24		1·51	18·12	24·16	30·20	36·24		18¼	18·25	24·33	30·42	36·50	
22	25		1·58	19·75	26·33	32·92	39·50		19	19·79	26·39	32·99	39·58	
23	26		1·66	21·78	28·78	35·97	43·16		20	21·67	28·89	36·11	43·33	
24	27		1·73	23·36	31·14	38·93	46·71		20¾	23·34	31·13	38·91	46·69	
25	28		1·80	25·20	33·60	42·00	50·40		21½	25·08	33·45	41·81	50·17	
26	29		1·87	27·12	36·15	45·19	54·23		22½	27·19	36·25	45·32	54·38	
27	30		1·94	29·10	38·80	48·50	58·20		23¼	29·06	38·75	48·44	58·13	
28	31		2·02	31·31	41·75	52·18	62·62		24¼	31·32	41·76	52·21	62·65	
29	32		2·09	33·44	44·58	55·73	66·88		25	33·33	44·44	55·56	66·67	
30	33		2·16	35·64	47·52	59·40	71·28		26	35·75	47·67	59·59	71·50	

TABLE III.

Scantlings of Rafters and Hips in couples for Common Tiled Roofs.

Span of roof.	Rafters spaced 1½ feet from centre to centre.						Hips.						Remarks.
	Length with allowance for eaves.	Scantlings. B.	Scantlings. D.	B.	D.	Contents.	Length with allowance for eaves.	B.	D.	B.	D.	Contents.	
FEET.	FEET.		INCHES.		¼INCHES.	C. FT.	FEET.		FEET.		INCHES.	C. FT.	
10	8	·25 of a foot.	·29	Three inches.	3½	·58	10¾	·25 of a foot.	·33	Three inches.	4	·90	By 'span' in this table is meant the clear width between the feet of the rafters.
12	9¼		·33		4	·76	12½		·38		4½	1·17	
14	10½		·38		4½	1·00	14		·42		5	1·46	
16	11¾		·42		5	1·24	15½		·46		5½	1·78	
18	13		·45		5¼	1·43	17		·50		6	2·13	
20	14¼		·48		5¾	1·71	18¾		·54		6½	2·54	
22	15½		·52		6¼	2·02	20½		·58		7	2·99	
24	16¾		·56		6¾	2·35	21¾		·63		7½	3·40	

TABLE IV.

Scantlings of Purlins and Common Rafters for Tiled Roofs, Trusses 10 *feet apart.*

Purlins (square section).					Rafters.					Cubic feet of timber in 100 square feet of roofing.	Remarks.
Distance apart from centre to centre.	Length allowance for seating.	Breadth.	Depth.	Contents.	Length.	Breadth.	Depth.		Contents.		
FEET.	FEET.	FEET.	INCHES.	C. FEET.	FEET.	FEET.	FEET.	INCHES.	FEET.		
4	11	·50	6	2·75	4	Three inches or ·25 of a foot.	·22	$2\frac{3}{4}$	·22	10·55	In applying this table to roofs an addition of $1\frac{1}{2}$ feet must be made to the total length of rafter to allow for the projection of the eaves.
5	11	·54	$6\frac{1}{2}$	3·23	5		·28	$3\frac{1}{2}$	·35	11·13	
6	11	·57	$6\frac{3}{4}$	3·48	6		·33	4	·50	11·36	
7	11	·60	$7\frac{1}{4}$	4·02	7		·39	$4\frac{3}{4}$	·68	12·20	
8	11	·63	$7\frac{1}{2}$	4·29	8		·44	$5\frac{1}{4}$	·88	12·69	
9	11	·66	8	4·89	9		·50	6	1·13	13·79	
10	11	·68	$8\frac{1}{4}$	5·20	10		·55	$6\frac{1}{2}$	1·38	14·40	

(3) CONSTRUCTION OF SPECIAL BUILDINGS.

ABATTOIRS OR SLAUGHTER-HOUSES.

Slaughter-houses are arranged according to the class of animals to be slaughtered therein, and, in India, are denominated bullock, sheep or pig slaughter-houses. The religious prejudices of the Hindus require that bullocks, sheep and pigs should be slaughtered apart from one another.

Requirements of a slaughter-house.—These may be briefly enumerated as follow:—

(1) The slaughter-house should be so enclosed as to permit ingress and egress being easily controlled by the superintendent in charge.

(2) The slaughtering space should be roofed in.

(3) The slaughtering sheds should be well ventilated.

(4) Cisterns should be provided to hold a sufficient supply of water.

(5) The floor of the slaughter-house should be arranged so as to enable it to be easily flushed from the cisterns.

(6) Drains should be provided for carrying away the liquid filth from the slaughter-house.

(7) Cesspools should be provided outside the slaughter-house into which the drains can discharge.

(8) The flooring should be of hard and impervious material.

(9) The lining of the walls should be of a hard and non-absorbent material.

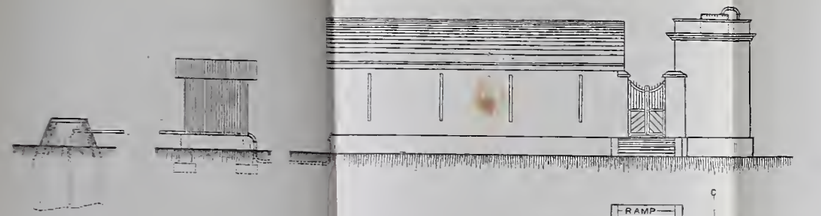
(10) Cooling and hanging rooms and lairs for animals are desirable.

The accompanying plates give designs for bullock and sheep slaughter-houses, in which the requirements above enumerated are embodied and are suitable for towns with populations not exceeding 30,000. The above designs will, however, be influenced in their application by the following circumstances and conditions:—

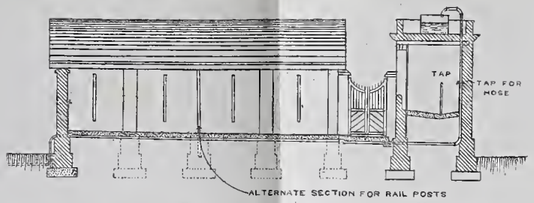
(1) The requirements of the town.
(2) Nature of the building materials available.
(3) Financial considerations.

Size of slaughter-houses.—The size of a slaughter-house naturally depends upon the number of animals to be killed. Statistics as to the number killed annually are available in most municipalities. No definite rule can be laid down, as in some parts of the country more beef and less mutton is eaten in certain towns than in others. In Madras city the

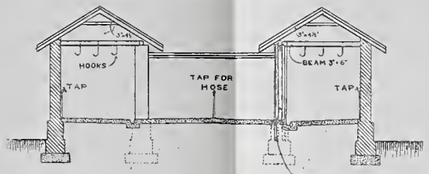
FRONT ELEVATION



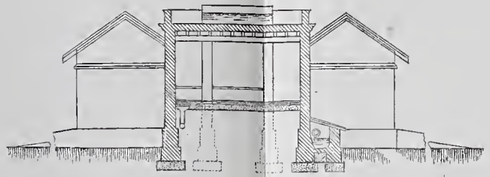
SECTION ON A.A.



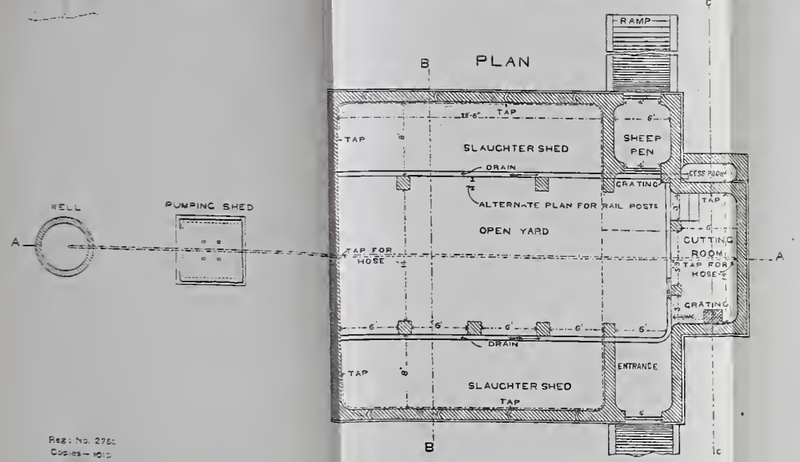
SECTION ON B B



SECTION ON C.C.

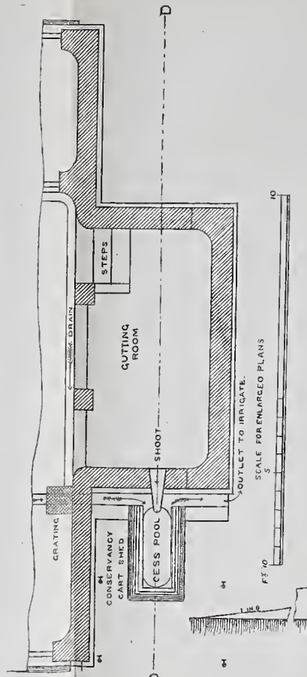


PLAN



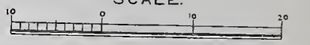
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ENLARGED PART PLAN



DESIGN FOR SHEEP SLAUGHTER HOUSE.

SCALE.



NOTE — THIS DESIGN IS FOR A POPULATION OF 15,000 ; INCREASE OR DECREASE BY ONE BAY FOR EACH 5,000 PEOPLE MORE OR LESS.

THE ENLARGED PART PLAN AND SECTION OF SLAUGHTER HOUSE SHEWS THE ALTERNATE ARRANGEMENT OF CESS POOL AND DRAINAGE IF CART IS SUPPLIED WITH STRAINER AS SHEWN

ENLARGED SECTION ON D.D.

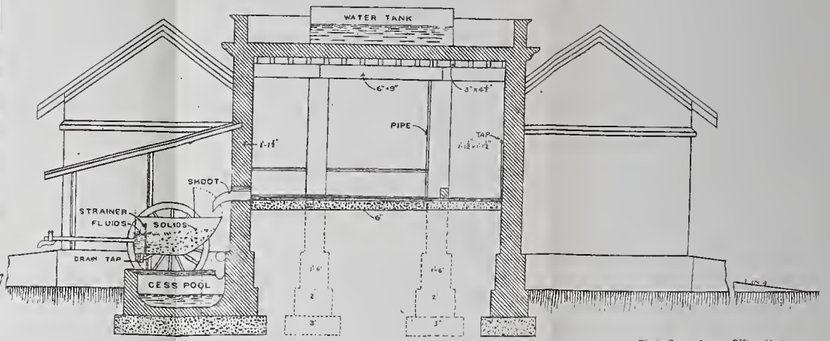
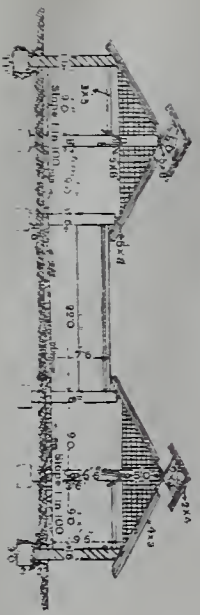
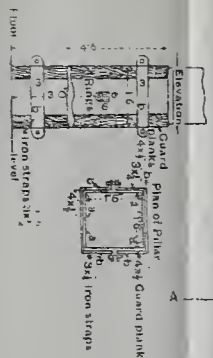
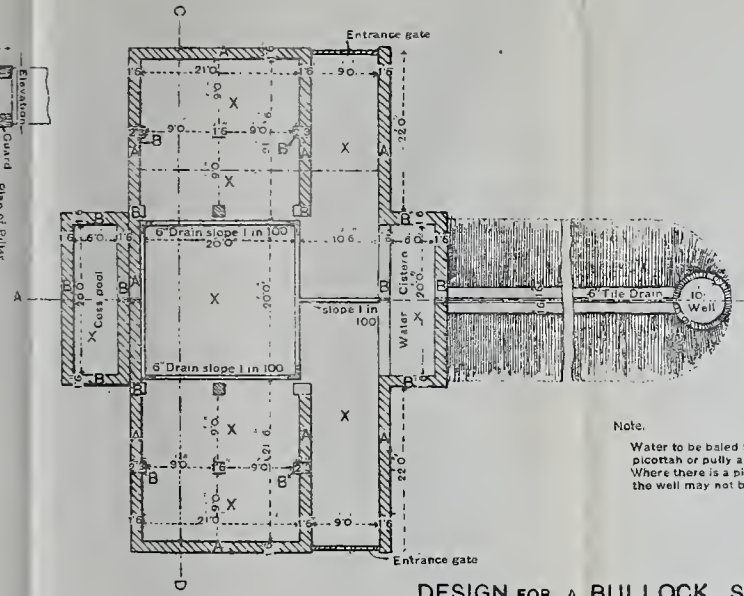


Photo-Zinco, Survey Office, Madras.
1895



SECTION ON C D





Note.

Water to be baled from well by picottah or pully and bucket Where there is a pipe water supply the well may not be required

DESIGN FOR A BULLOCK SLAUGHTER HOUSE

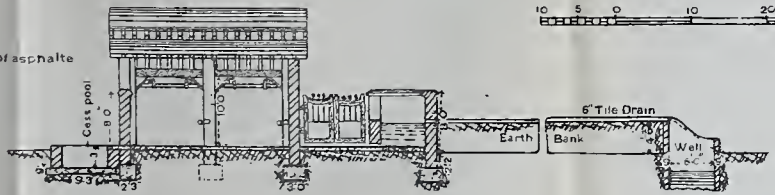
REFERENCE

(A) Walls marked A to be of Brick in Clay plastered with Cement

(B) Pillars and walls marked B to be of Brick in Chunam plastered with Cement

X Flooring and Pavement marked X to be of asphalte Granite or cement plaster over concrete.

SECTION ON A B



Scale

10 5 0 10 20 30 feet

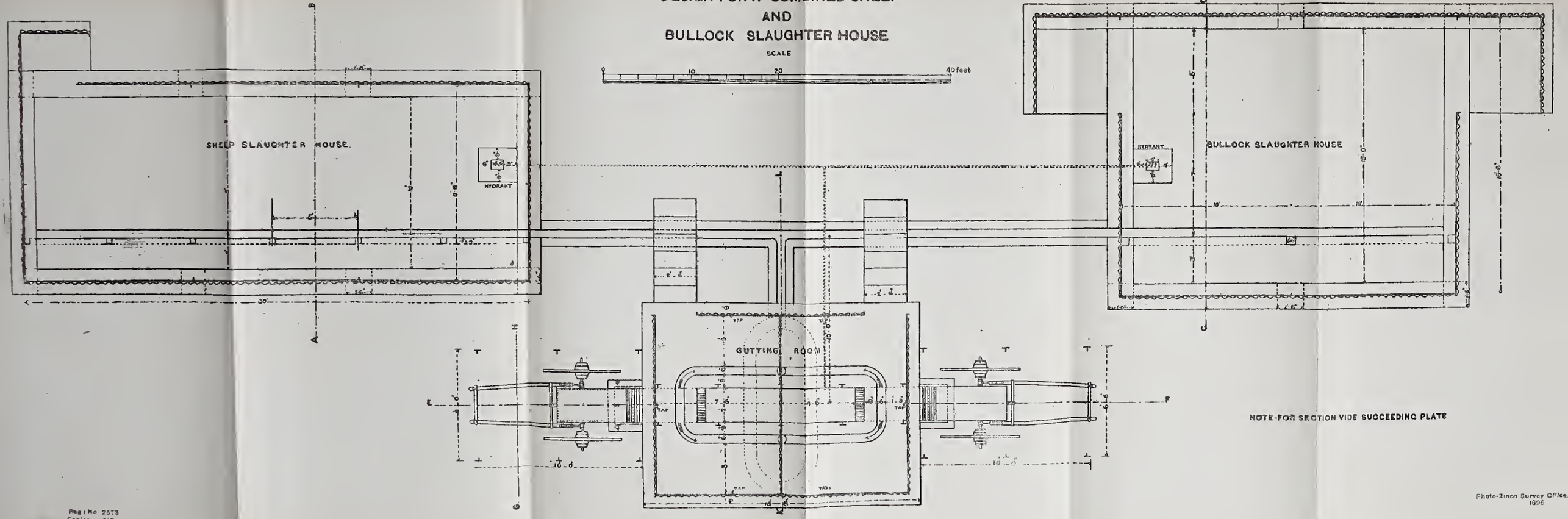
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1896

DESIGN FOR A COMBINED SHEEP AND BULLOCK SLAUGHTER HOUSE

SCALE

0 10 20 40 feet

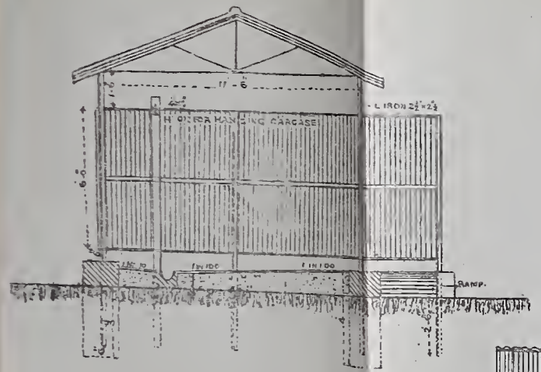


NOTE-FOR SECTION VIDE SUCCEEDING PLATE

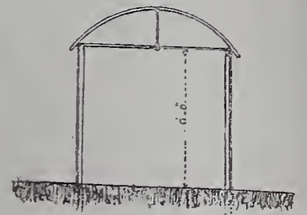
Photo-Zinco Survey Office, 1896

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SECTION ON AB

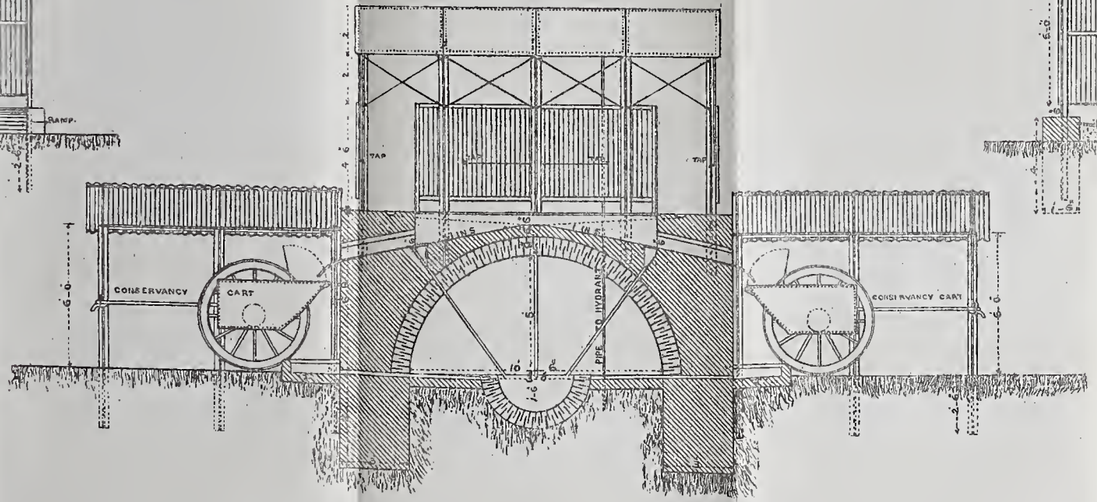


SECTION ON GH.

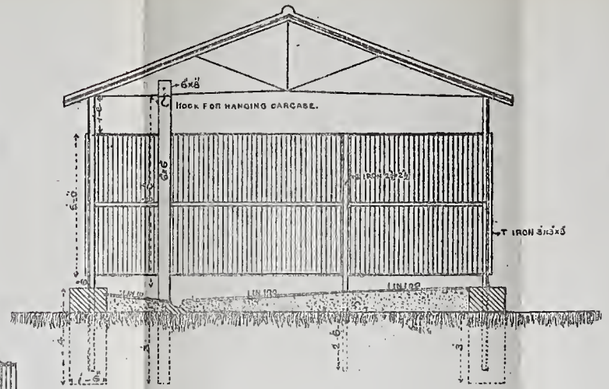


NOTE-FOR PLAN VIDE PRECEDING PLATE

SECTION ON EF.



SECTION ON CD.

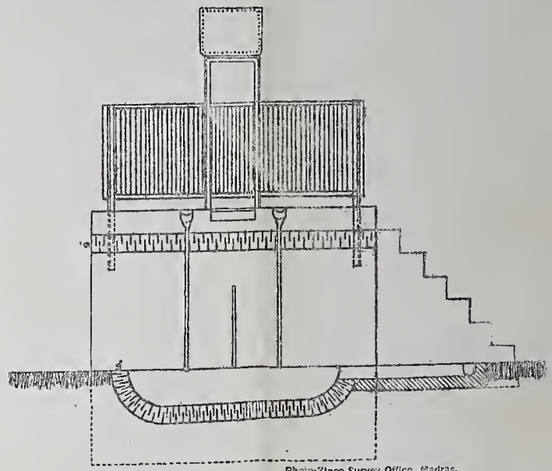


DESIGN FOR A COMBINED SHEEP AND BULLOCK SLAUGHTER HOUSE

SCALE

0 10 20 40 Feet

SECTION ON K.L.



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1896

annual consumption is about one bullock per 45 persons and one sheep per person. The size requisite for a sheep slaughter-house would be determined thus: taking the population of a town to be 15,000, we have 15,000 sheep to be slaughtered in a year, or 42 sheep on an average daily. A period of from three to four hours is the usual duration of slaughtering. Taking the minimum period of three hours, 14 sheep would require to be slaughtered per hour. To slaughter one sheep and skin it, requires about 20 minutes, so that three sheep will be killed per hour and therefore floor space for $\frac{14}{3}$, or, for five sheep, will be required. Let this be increased by 50 per cent. to allow for fairs and festivals, or, say, a floor space for 8 sheep is required. The floor space required for one sheep is about 60 square feet which is $8' \times 7\frac{1}{2}'$. In the design there are two slaughtering sheds each with four bays measuring $8' \times 7\frac{1}{2}'$. This size is therefore sufficient for a town with a population of 15,000. When the population is more or less, the number of bays will have to be increased or decreased, the number required being calculated as above. The water cistern and cesspool may also be altered in proportion. The entrance passage should not be less than $4\frac{1}{2}$ feet in width and it need not exceed 6 feet. The width of the open space between the sheds may be reduced to 12 feet for a smaller slaughter-house, but not under 12 feet in any case. The height of the sheds would remain unaltered whatever be the other dimensions of the slaughter-house.

Masonry.—The foundation and superstructure of slaughter-houses may be in either stone or brick; the slaughter-house should be built in chunam, but where economy is the object, portions of the structure may be built in clay except the following, *i.e.*, water cistern, cesspool, drains and pillars which should, as a rule, be constructed in chunam.

Plastering.—The whole of the interior walls and pillars of the building should be plastered with Portland cement mortar not less than half an inch thick in the proportion of 3 of sand or 2 of sand to 1 of cement. Over this there must be a rendering of neat cement. The outside of the building, if of brickwork, should also be plastered with cement, but, if of stone, pointing with cement will suffice.

Flooring.—It is an essential requisite of a slaughter-house that the floor should be evenly paved. Notwithstanding that there is some inconvenience to the butchers by reason of a certain slipperiness with a smooth floor, this, when weighed against the quick removal of blood, garbage, &c., cannot be

*

considered a grievance. It is not advisable that the floors of a slaughter-house should slope towards the drains; in the first place the slope would cause the floor to be more slippery than if level; in the second place the cleansing probably would not be so effectually done; on the slope it could be sluiced with water, on the level manual labour will be required and if squeegees, such as are used for railway station paved platforms, are employed, the cleansing can be very effectual. The floor may be formed of—

(1) Flags.
(2) Granite stones dressed fairly smooth.
(3) Well-burnt brick on edge in cement or hydraulic mortar plastered over with cement.
(4) Concrete in cement or hydraulic mortar plastered over with cement.

When flags are used the edges should be squared, so that they may be laid with close joints. The flags should be laid over a layer of concrete not less than 4 inches thick, as a firm foundation is necessary. The flags shall be jointed with Portland cement. The flags should be such that their individual area does not exceed one square foot for each half an inch of thickness.

A slaughter-house should not be paved with square granite stones unless their surfaces are finely chisel-dressed. The cost of doing so will be prohibitive in most places.

When bricks on edge are used, they should be laid in cement or hydraulic mortar on a foundation of not less than 4 inches of concrete. The floor must then be plastered with Portland cement mortar not less than half an inch thick consisting of 2 or 3 of sand to 1 of cement, laid in one coat with a rendering of neat cement.

When concrete in cement or hydraulic lime is used, the concrete should be not less than 9 inches thick and be plastered over with cement as above described.

Drainage.—The drains should have a fall of not less than 1 in 100, but greater than this if it can be arranged. The drains should be 6 inches in width. The bottom should have either a semi-circular or oval shape, preferably the latter. The drains should be formed of concrete in cement or hydraulic mortar, and coped stone with brick on edge in cement and plastered with cement, or to be made of some equally non-absorptive material and of a design such as will not allow of any leakage.

Cesspools. — The cesspools ought to be outside the slaughter-house. They should be of ample capacity to receive all the solid matter from the slaughter-house and also a portion of the water used for cleansing. If an overflow is provided from the cesspools and no sewers exist, the water overflowing should be used to irrigate some small area of land. The cesspools should be built in chunam mortar and plastered with cement in the proportions already stated.

Water-supply. — The cistern should be so arranged that it can be filled from the outside. The bottom of the cistern should be at a sufficient heigt to enable every portion of the floor of the slaughter-house being flushed. The cistern should be built in chunam and plastered with cement.

Design.—The roof may be a tiled one on wooden rafters or covered with corrugated iron sheets if considered desirable on the grounds of economy and facility of erection. Slaughter-houses ought, if possible, to consist of open sheds, all surrounded by a brick wall or other closed fence. This plan admits of thorough circulation of air.

LATRINES.

Latrines are either on the water carriage or dry-earth system.

Water latrines.—Water closets are applicable only to towns possessing a system of underground close sewers. A design of a water latrine adopted in Calcutta will be found in one of the attached plates.

Dry-earth latrines.—A design for an all-round good latrine on the dry-earth system is a desideratum. A good design for a latrine is one of the most difficult problems presented in this country and when an engineer has to design a cheap and efficient latrine at a low cost, the problem is doubly difficult. The poverty of Indian towns is proverbial, and financial consideration will not, in most cases, allow of latrines being constructeed as they ought to be. It is a rule worthy of observance never to erect permanently a bad latrine ; if funds do not permit the erection of a good one, the want should be tided over by some temporary structure until it is seen what the preparation of a new budget may bring forth.

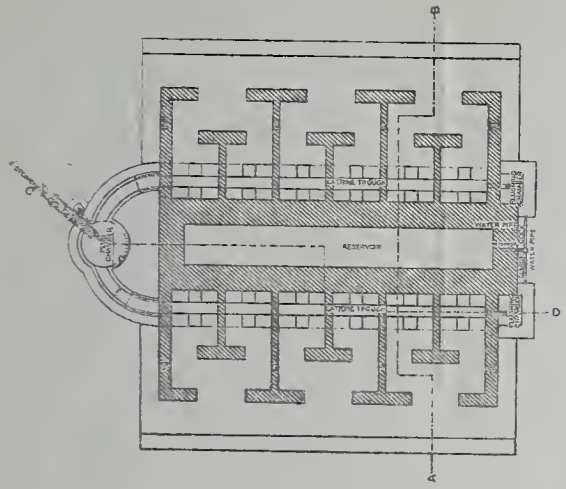
Sanitary principles.—There are certain sanitary principles which must be adhered to in designing latrines of

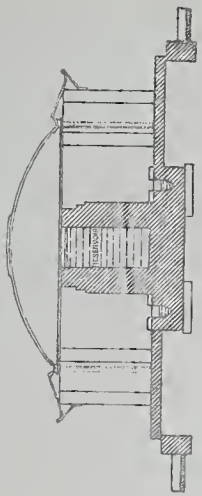
however cheap a description. These principles may be enumerated briefly as follow :—

(1) Privacy, (2) an impermeable floor, (3) separation of urine from the solid matter and its collection in cesspools or tubs outside the enclosure of the latrine, (4) protection from sun and rain, (5) thorough ventilation.

Points in design.—Public as well as private latrines should be constructed so as to allow of a considerable amount of privacy. It must be remembered that the public latrines have to be frequented by women as well as men, though perhaps the former are driven there by police regulations, and while therefore public latrines are a necessity, it is desirable, as far as possible, to encourage a proper sense of decency, or a decay of morality will be an inevitable result. To secure thorough privacy each seat or squatting place should be separately enclosed with a door for entrance. This arrangement is rather expensive and usually a whole range of seats is enclosed *en bloc*.

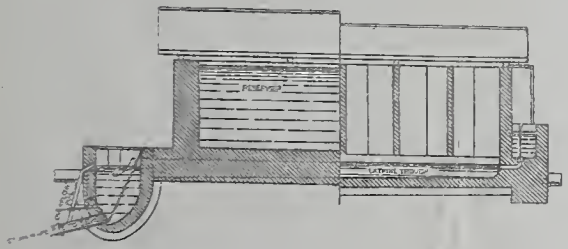
Corrugated iron sheets riveted or bolted to iron standards sunk into the masonry of the floor form the best sort of enclosure and have an immense superiority over walls of other materials like brick and stone, being impervious to moisture and unassailable by insects of any kind. But the cost of iron work in small outlying villages is often prohibitive and the use of stone or brick walls is then unavoidable. When stone or brick is used it should be a rule that the interior of the walls should be plastered with cement. The whole of the interior of the latrine should possess a smooth and impermeable floor. Glazed flooring tiles and glazed stoneware drains answer the purpose best; they are expensive, and their use, therefore, in most cases prohibitive. Cement plastering renders the surface sufficiently smooth and impervious. The design should admit of the urine and excreta being received in separate receptacles. When this course is adopted, the smell is not as offensive as when urine and excreta are received in the same receptacle. A roof over latrines is desirable not only for the protection of those who frequent them from sun and rain, but also for the prevention of that disgusting and filthy state in which latrines without roofs are usually found after rain. While enclosures and roofs are necessities, care should be taken to design them in a manner such as will admit of the greatest possible ventilation. A good practice is not to roof the whole area of the latrine enclosed, but only the range of seats, leaving the passage open to the sky. Where the roof





CROSS SECTION ON A-B.

LONGITUDINAL SECTION ON C.D.



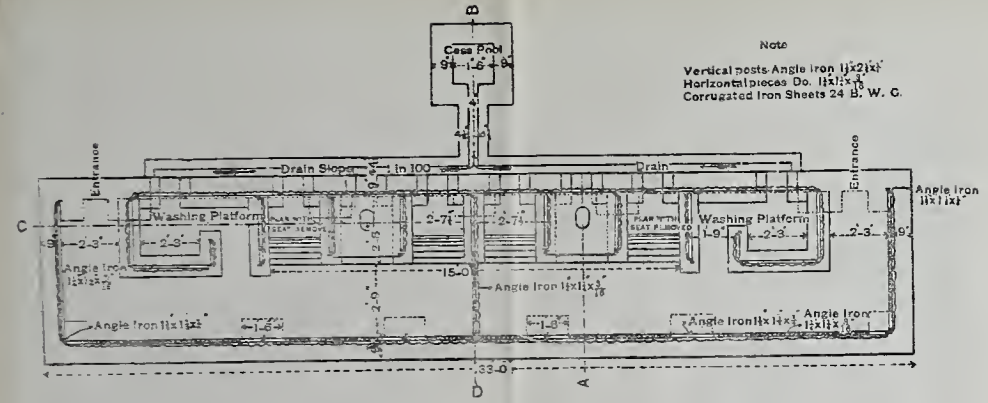
PLAN
OF
CALCUTTA LATRINE

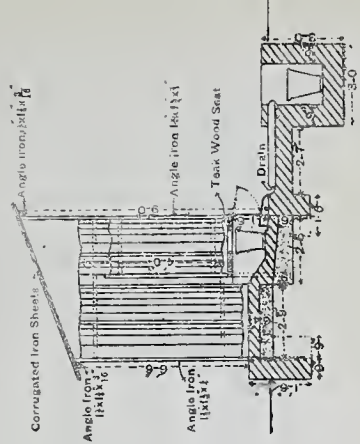
SCALE



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1895





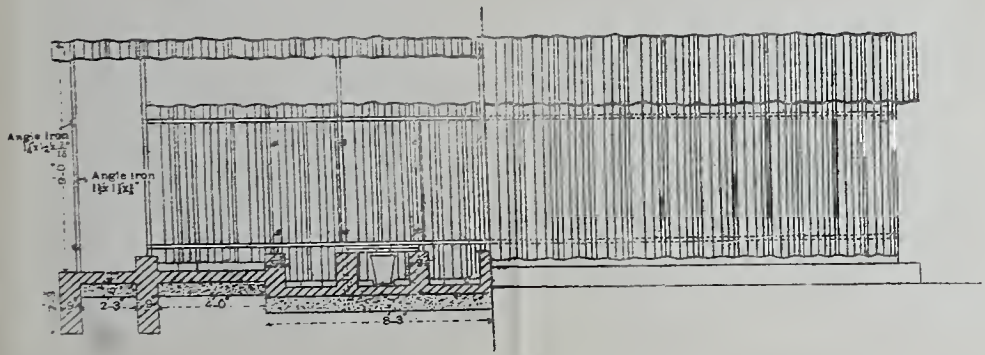
SECTION ON A B

DESIGN FOR A LATRINE

SCALE

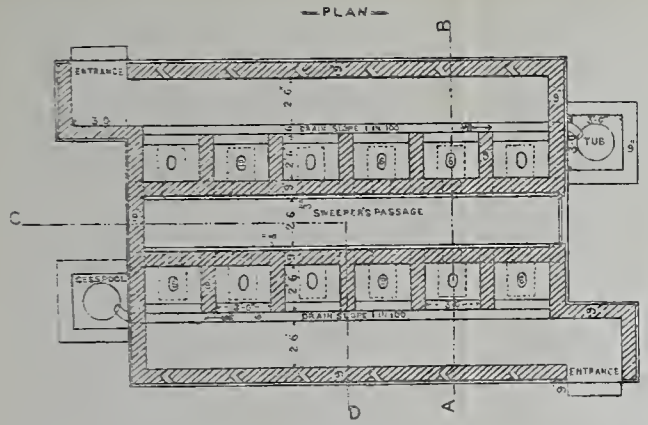
0 1 2 3 4 5 6 7 8 feet

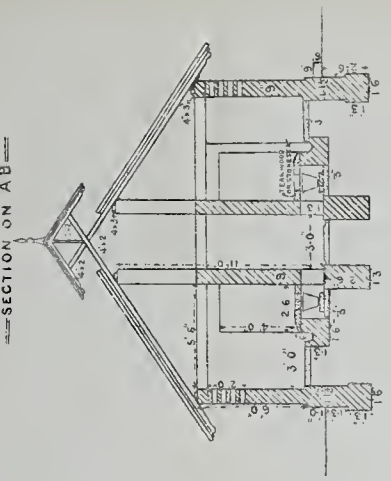
SECTION ON C.D.

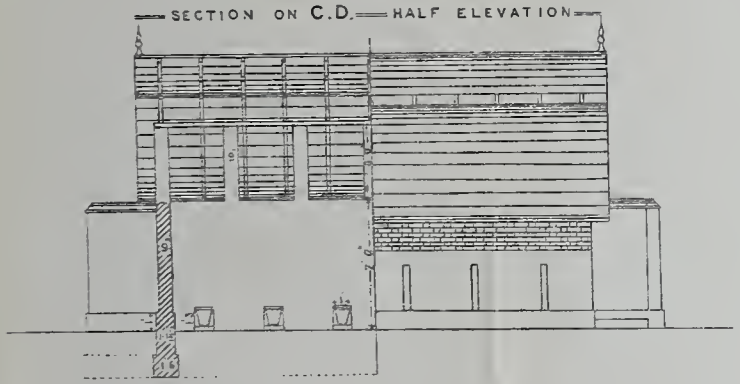


HALF ELEVATION.

Photo-zinco, Survey Office, Montreal.







DESIGN FOR A LATRINE

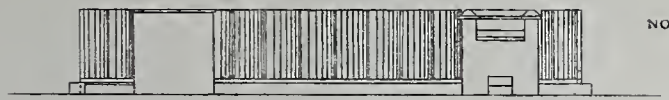
SCALE

Inches 12 0 1 2 3 4 5 6 7 8 9 10 Feet

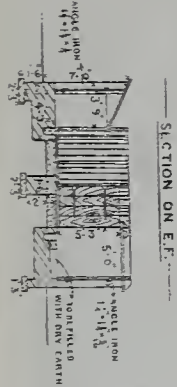
Reg No. 2444
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Photo-Zinco., Survey Office, Madras.
1895

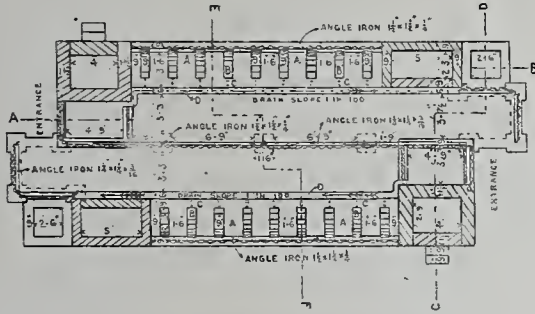
FRONT ELEVATION

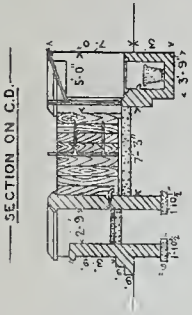


NOTE. Vertical Posts—Angle Iron $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{1}{4}$
Horizontal Pieces Do. $1\frac{1}{2} \times 1\frac{1}{2} \times \frac{3}{16}$
Corrugated Iron Sheets 24 B. W. G.



SECTION ON E.F.



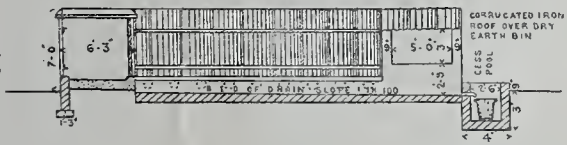


SECTION ON C.D.

REFERENCE

A. A—Are Foot Rests
B. B—Are Receptacles to be filled two-thirds with dry earth for receiving excreta. Urine is also discharged into the same receptacle and filters through the earth and is carried by weep-holes C. C. into drain D. D.

LONGITUDINAL SECTION ON A.B.



DESIGN
FOR A
LATRINE

SCALE
Inches 0 5 10 20 Feet

Reg. No. 2464
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1895

PLAN

OF A

DOUBLE LATRINE

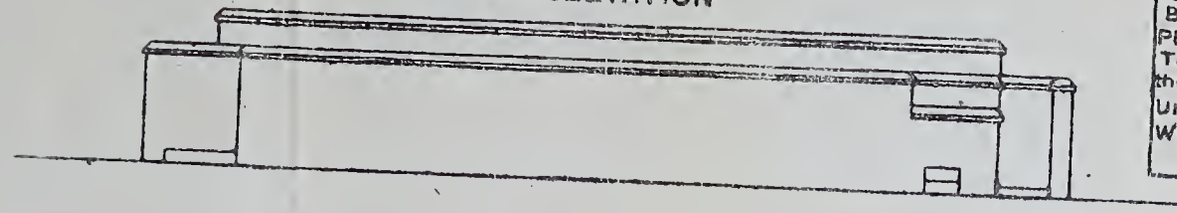
WITH 10 SEATS IN EACH COMPARTMENT

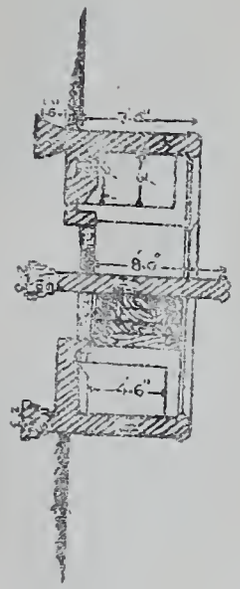
Scale

10 5 0 10 Feet

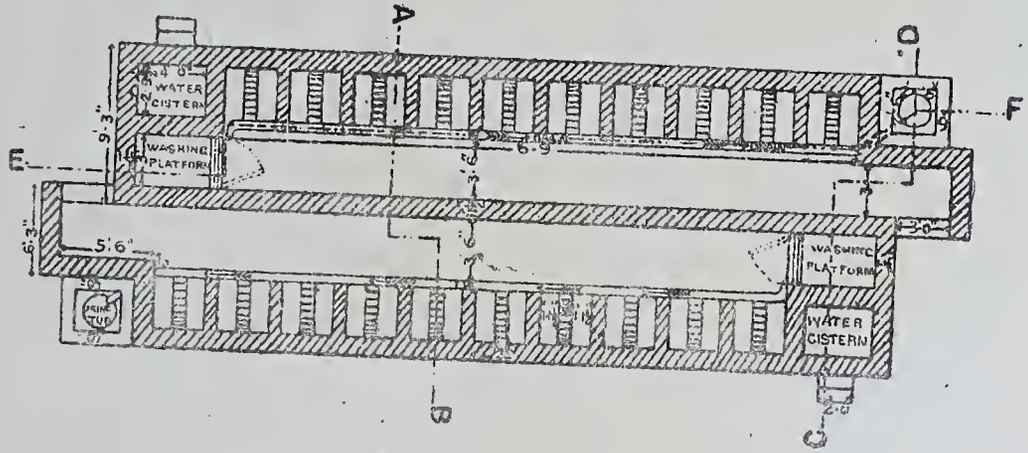
Description of work	Quantity
Earth work	82 C.Yds.
Concrete	194 C.Feet
Brick in chunam	3231 Do.
Plastering with cement	44 Sq.feet
Teak wood doors to the washing Platform	2 Nos.
Urine tubs	2 Do.
Wooden Covering to Urine tubs	2 Do.

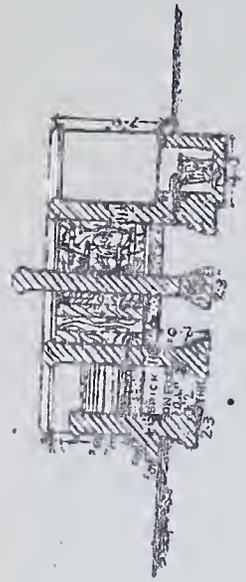
FRONT ELEVATION





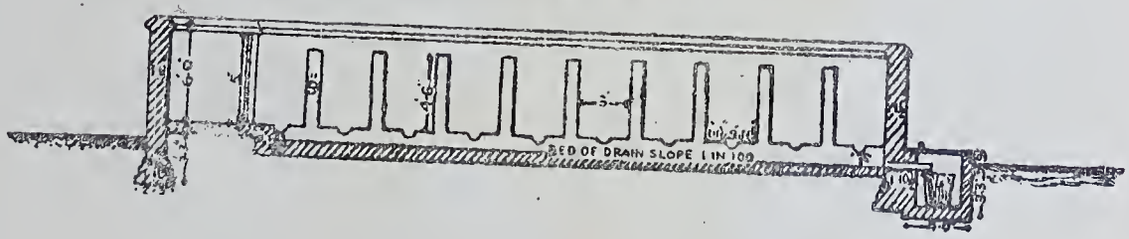
SECTION ON A.B.





SECTION ON C.D.

LONGITUDINAL SECTION ON E. F.



Register No. 2283
Copies 1910

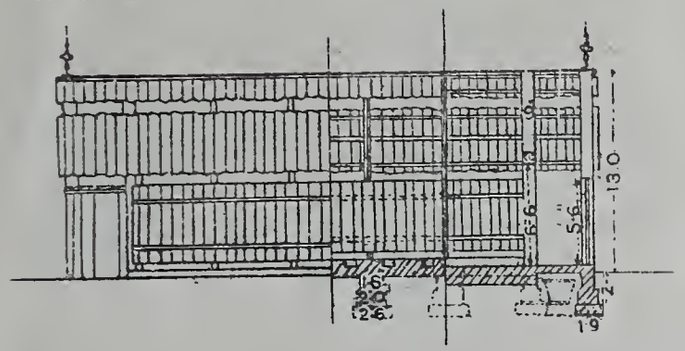
Photo-Zinco. Survey Office Madras.
1896

DESIGN FOR A LATRINE

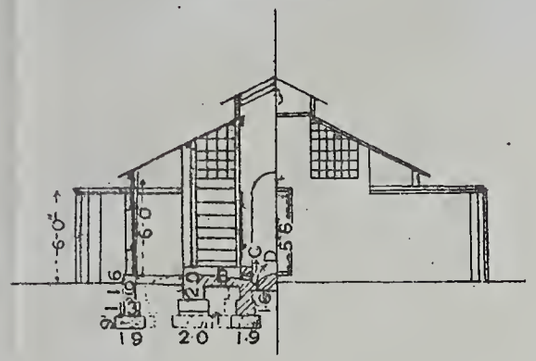
SCALE

0 5 10 20 30 Feet

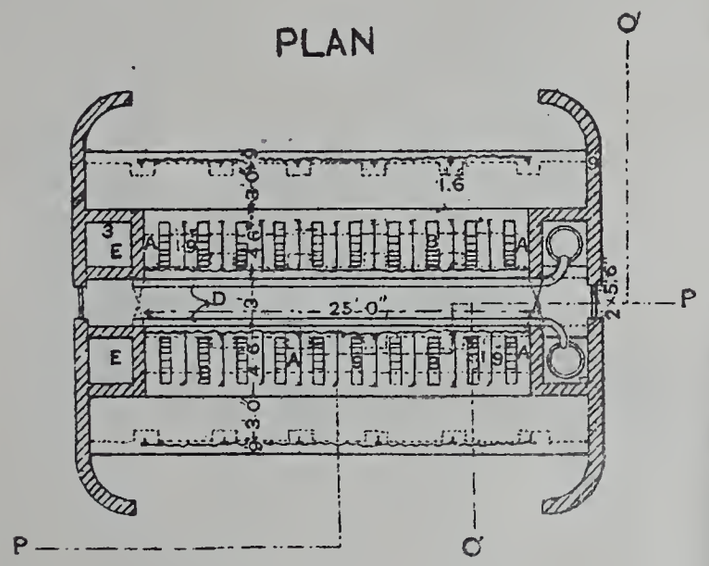
HALF ELEVATION — HALF SECTION P.P.



SECTION Q.Q



PLAN

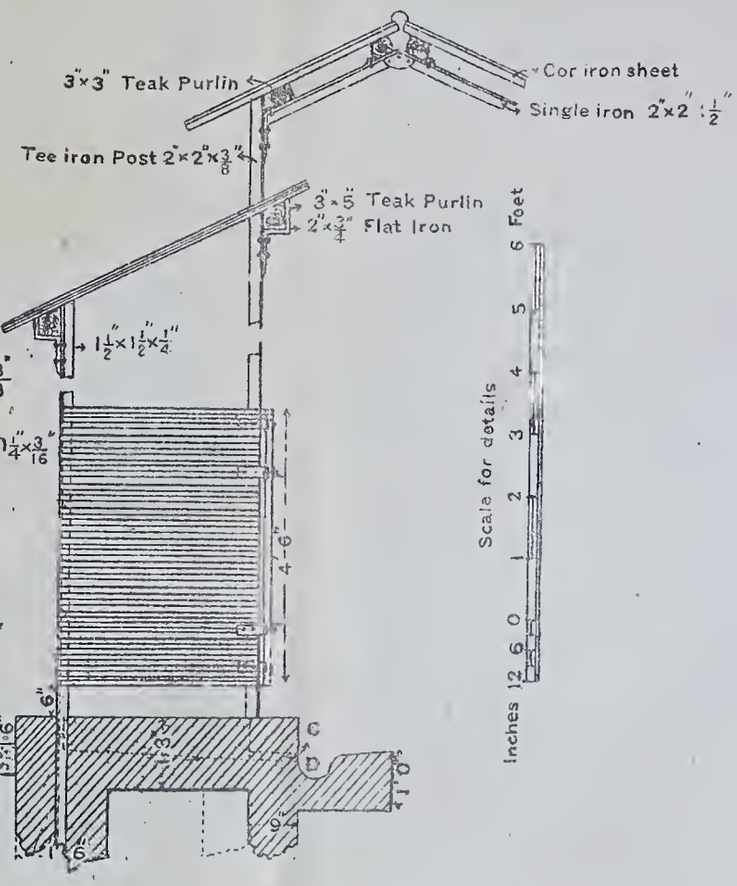


REFERENCE

A. A. are foot rests

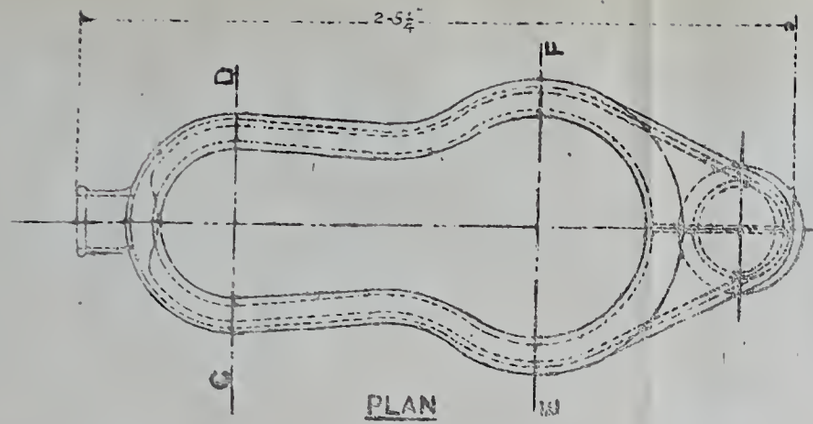
B. B. Are receptacles to be filled two-thirds with dry earth for receiving excreta. Urine is also discharged into the same receptacle and filters through the earth and is carried by weep holes C. C. into drains D. D.

E. E. are receptacles for storing dry earth



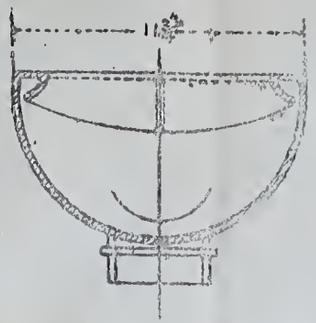
Reg: No. 2445
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Photo-Zinco., Survey Office Madras.
1895

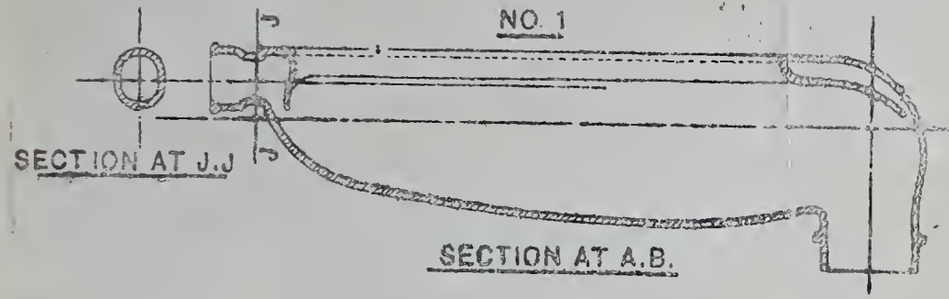


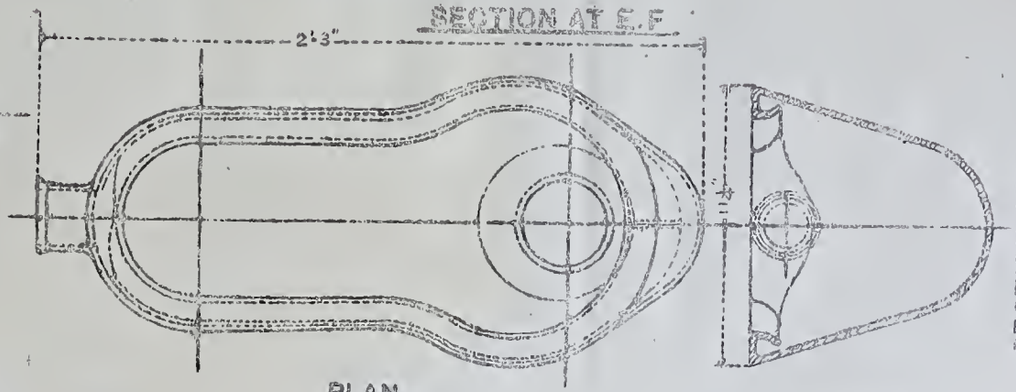






NO. 1



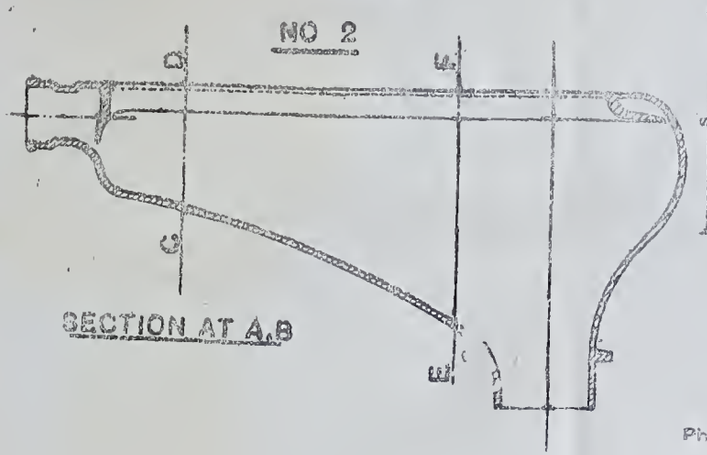


THE HINDUSTAN CLOSET
(PATENT)
RICHARDSON & CRUDDAS

ENGINEERS

BOMBAY

NO 2





Cost delivered in Bombay Rs. 30

These are stone ware closets which can be provided with Marble slabs at an additional cost of Rs. 10 each

Register No. 2284
Copies 10:0

Photo-Zinco. Survey Office Madras.
1893

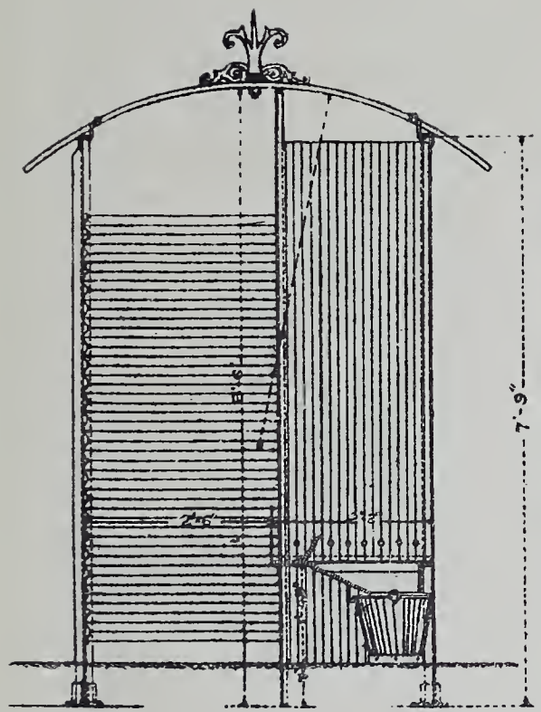
5 SEAT RANGE

HORBURY'S PATENT LATRINE

RICHARDSON & CRUDDAS

ENGINEERS

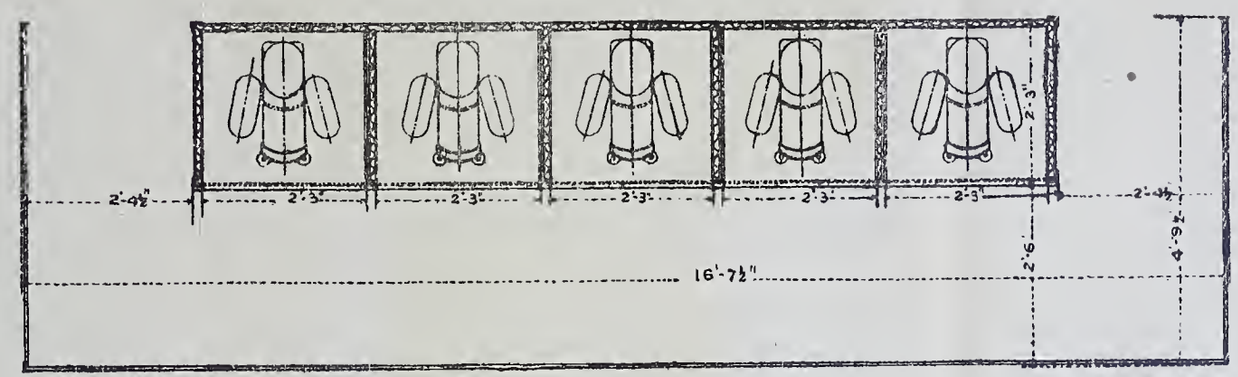
BOMBAY



Cross Section

SCALE

Inches 12 6 0 1 2 3 4 5 Feet

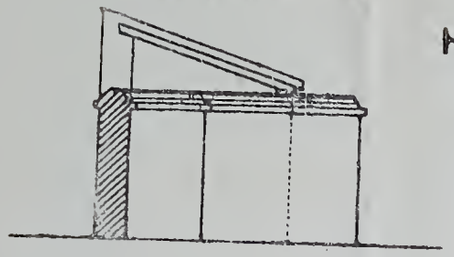


Cost Delivered in Bombay Rs. 210

Register No. 2283
Copies 1010

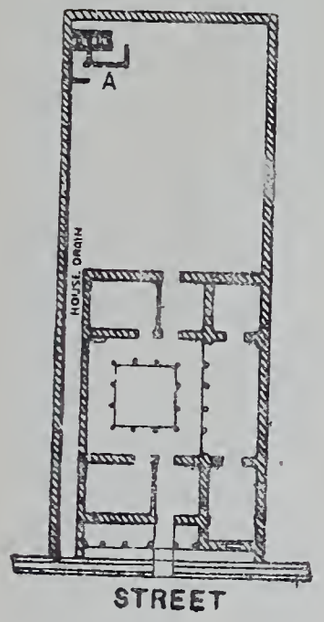
Phot-Zinco., Survey Office, Madras.
1895

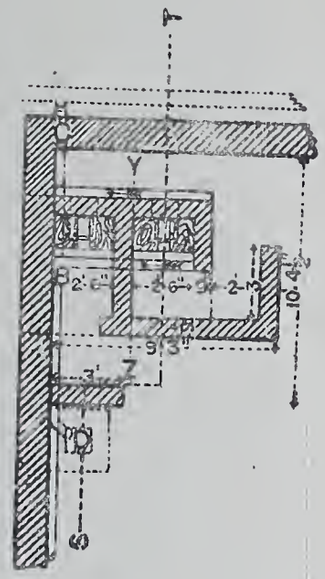
FRONT ELEVATION



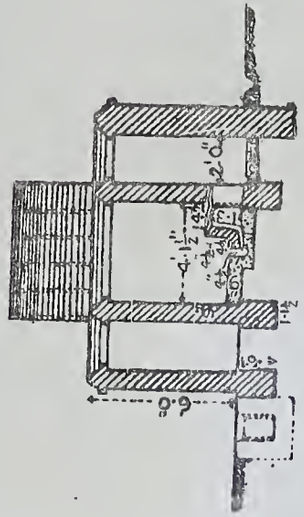
PLAN
OF A
HOUSE LATRINE
Scale
Inches 0 1 2 3 4 5 Feet

KEY PLAN





SECTION ON S.T.



NOTE

The plan shews a private latrine suitable for males and females. If only one closet is required, the portion to the right of the line Y. Z. may be omitted.

The brick work of the latrine above seat level may be built with mud; below seat level, it should be with chunam. The floors should be formed of chunam concrete; if they cannot be so made, then of some hard impervious materials, such as clay well beaten in.

The concrete floors, drains and all brick work below seat level should, if possible, be plastered with portland cement; if this cannot be done, then chunam plaster should be used.

There may be roofs or not as convenient. The roofs may be of tiles, but thatch and bamboo roof may be used when nothing better can be afforded.

The receptacles provided for, are simple Kerosine tins; these should be provided with handles.

The latrine as designed is supposed to be in the situation shewn at A in the backyard of the house (on left of drawing.) If the drainage of the house is to the front, the drains should fall into the drain marked B. If the drain is in rear of the backyard, an opening must be provided through the compound wall at the point marked C. If there are no drains near the house, a receptacle and cistern must be provided, as at D.

The seats or foot rests may be made preferably of Cuddapah slabs, of granite slabs, or of wood.

When the latrine has been used, the pails (Kerosine oil tins) should be removed from the back and cleaned in the space behind the latrine and at once replaced.

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1896

rests on the walls, the height from floor to eaves should not be less than 8 feet, but the walling should not be more than 6 feet in height, the upper 2 feet being open for ventilation.

Donaldson's patent latrine has lately been received with much favour; it aims at the separation of the liquids and solids, the liquids being received either in a pail in front of the solids or in a drain running under the whole range of seats. The platform for the separation may be of steel or stoneware. The foot-rests are in either case roughened.

This form of latrine can be covered with any kind of roof, a cheap tiled covering supported on a *bullah* and bamboo frame and screened with matting being perfectly sanitary and efficacious, but a stronger framework of more permanent character is recommended.

One form of latrine has the basement of glazed stoneware. Into low level drains all the washings of the surfaces below the line of the platform drains are collected and flow into utensils placed at the ends of the structure. All the surfaces both horizontal and vertical, above and below, being of glazed stoneware set in cement, they are impermeable to sullage, indestructible, and easily cleaned.

The platforms can be built in either double or single lines and in any number. It is a design which is being adopted in large installations by the Calcutta municipality.

Other designs of latrines.—Plates accompanying shew other designs of latrines suitable for the varied requirements of villages or towns; these cost from Rs. 200 to Rs. 1,000 each. Horbury's patent latrine, which is also illustrated, is well suited for railway stations, hospitals, schools and similar institutions, but is not much favoured by natives generally. It can be made movable by placing it on wheels and a trench can then take the place of buckets.

Private latrines.—House latrines must be constructed on the general principles indicated for public latrines. A design for a cheap house latrine is attached.

It is a common practice to have private latrines in houses in that portion of the house next to the street. This is, no doubt, convenient for the sweeper's entry and for cleansing, but for any other reason it is a most unsuitable position, situated, as it probably is, in a passage under the living room or in a passage uncovered which passes up alongside the living rooms of the house. If the privy is not in the position indicated, it is probably in the backyard adjacent to the well; both these sites are equally bad. The privy is best apart from

the house, but it ought to be far from the well. Wher circumstances will not permit it to be so, it is better t omit either the privy or the well, and power is given by th Municipal Acts to object to the situation of privies. Wher it is thought desirable to allow both the privy and the wel though within an undesirable distance of each other, th well should be required to be puddled round with at least foot of clay, and the floor and drain of the privy should b formed of cement concrete or other impervious material, an in such form that no effluent matter can possibly run toward the well.

Temporary latrines.—Latrines for temporary purpose such as at fairs or festivals, are best formed by long pits bein dug with foot-boards placed over them, the whole surrounde by a movable screen. The pit is partially filled with ear daily, and when almost full the screen is moved forward an placed round a parallel pit to the first. The screen can made of mats supported on bamboos, but Horbury's latrin made of corrugated iron, as already noted, can be suitab arranged for the same purpose.

MARKETS.

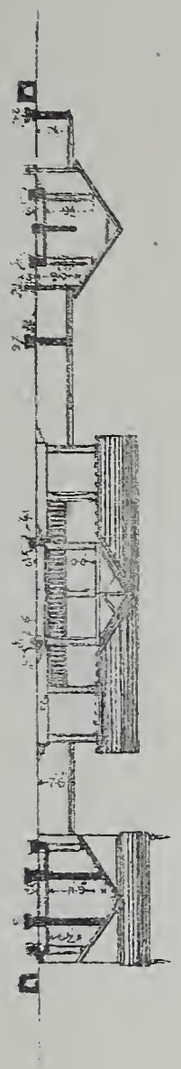
Markets usually provide accommodation for (1) grai fruits and vegetables, (2) game and poultry, (3) mutton, beef, (5) pork, (6) fish, and (7) sundry goods. The religio prejudices of the various sects of an Indian commun demand that several of the above articles should be s separately and in distinct buildings. For the convenience the general public and proper municipal supervision, pla for the sale of the various articles should be grouped togeth but so arranged that the meat and fish stalls should h separate entrances.

Market yard.—The market yard should not be eleva more above road level than what is sufficient for the pro drainage of the place. There should be no steps up or do at the entrances to markets. The approaches must be slo up from the road level to the level of the ground in market yard. The 'gangways' or the vacant space betw the sheds for the passage of the people should not be than 6 feet wide.

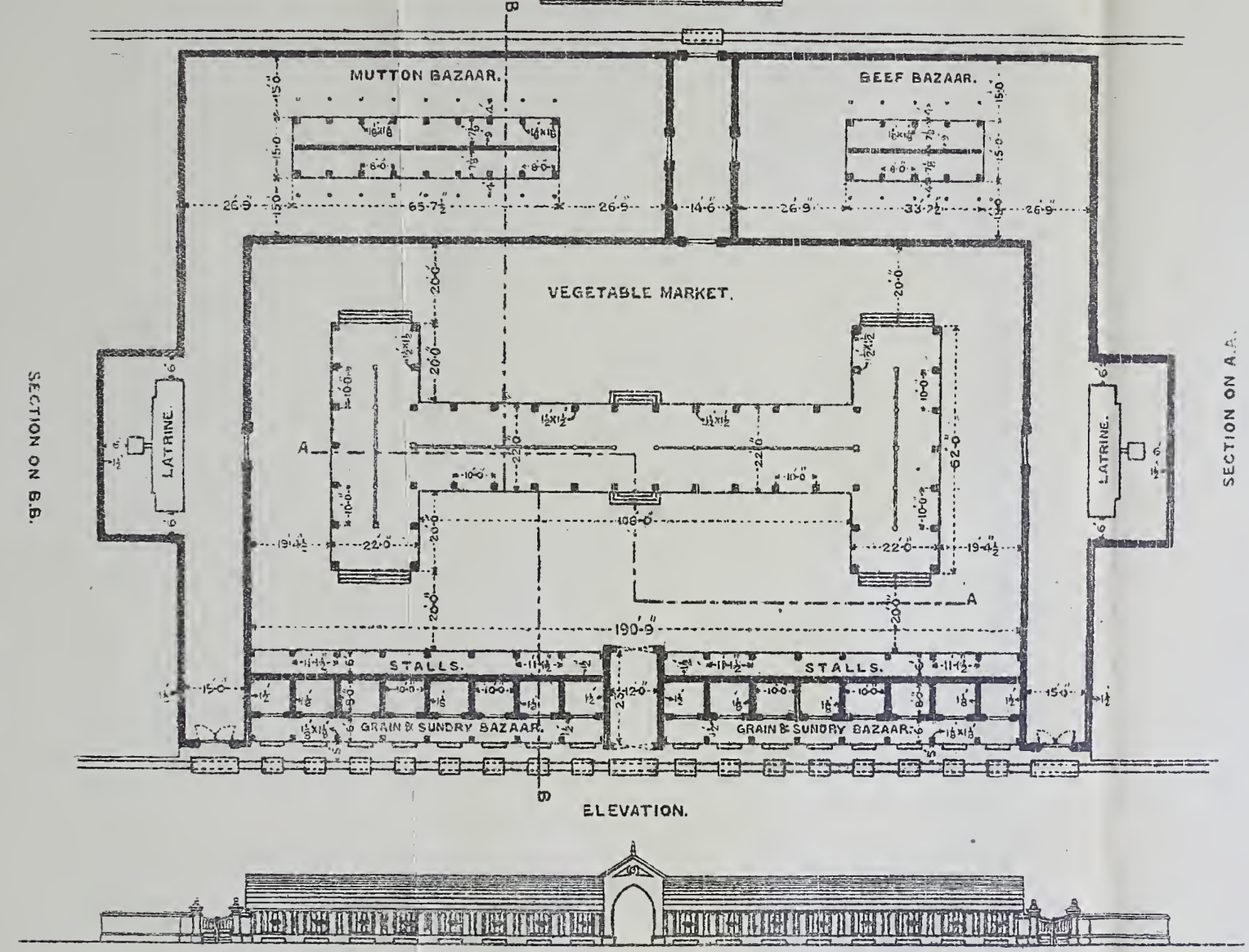
Sheds.—The sheds should have verandahs or overhang roofs for the protection of buyers from sun and rain. T

DESIGN FOR A MARKET FOR ABOUT 30,000 PEOPLE.

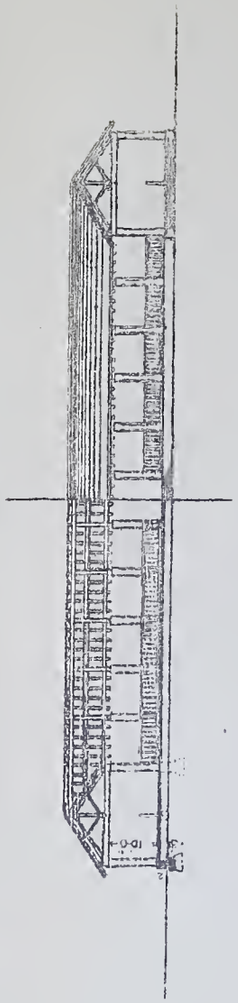
SCALE.



SECTION ON B.B.



ELEVATION.



SECTION ON A.A.

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1895

should be as lofty as possible and thoroughly ventilated. Thick masonry pillars are objectionable in many ways. Old iron rails are an excellent substitute for masonry pillars.

Basement.—The basement of the sheds should be raised at least 2 feet above the level of the market yard. The floor of the sheds may be formed in one of the several ways recommended for flooring slaughter-houses.

Drains.—The yard itself should be paved or gravelled and drained. A convenient position for the drains is down the middle of each gangway. The drains are best formed of two slabs of stone laid together and slightly tilted up, the ground on either side sloping towards the drain.

Fish stalls.—Fish stalls should be provided with water cisterns and at the end of each range of stalls water should be available.

Butcher stalls.—Butcher stalls should be floored with dressed stones or otherwise constructed of substantial materials so as to resist the blows from the choppers. These stalls should also be provided with cross-rails overhead and hooks for hanging meat.

Latrines.—Markets should be provided with latrines and a sufficient number of dust or refuse bins.

Design of markets.—The plate attached illustrates a design for a market suitable for a small town or village.

HOSPITALS AND DISPENSARIES.

Establishment of hospitals.—It is interesting to note that hospitals were established in India so long ago as during the time of King Asoka who flourished in the third century B.C. His edict establishing hospitals throughout his dominions is still extant and engraven on the living rock at Girinar in Guzerat.

Only one of these hospitals remained at the beginning of the present century and that one, curious to say, was for the treatment of animals. It covered 25 acres and was divided into proper wards.

The present system of medical relief owes its establishment to British occupation; between 300 B.C. and the British occupation, medical institutions were almost non-existent in India. At the present time few towns and villages are not possessed of a hospital or dispensary.

Classification of hospitals.—Civil hospitals and dispensaries are divided into classes—

(1) State hospitals.
(2) Municipal and local fund institutions.
(3-A) Private hospitals.
(3-B) State aided hospitals.

These classes have been graded by the Sanitary Board, Madras, as follows :—

Grade A. General hospitals, 50 beds and upwards.
Do. B. Cottage hospitals, 10 to 49 beds.
Do. C. Hut hospitals, 1 to 9 beds.
Do. D. Dispensaries for out-patients only.

Hospital sites.—After deciding to construct a hospital or dispensary, the first point to be considered is where it ought to be placed. There is no doubt that it is always desirable that such institutions should be placed as near as possible to the bulk of the population they have to serve; but there are other considerations and these are—

(1) The aspect and conformation of the ground.
(2) The nature of the soil.
(3) The area in relation to the number of beds.
(4) Cost of the site.

The first three are questions of hygiene, the last, one of economy ; the last ought never to be subordinated to the others and the tendency to do so must be remembered.

(1) The aspect must be considered in relation to access of sun-light and to prevailing winds, their healthiness or the reverse. Generally the first consideration will be easily complied with and the second should be decided in relation to the monsoon winds. Where there are winds blowing from a malarial quarter, the building ought to be placed so as to be protected from such winds or some screen formed for the purpose ; certain kinds of trees would be useful for this purpose.

(2) The healthiness or unhealthiness of a particular soil is affected by its power of retaining heat and by the level of the ground water. A low level of sub-soil water is preferable to a high level, but a permanent level is to be preferred to even a fluctuating low level ; a high level may, in most places, be cured by drainage. Any made-soil is unsuitable for hospital sites ; if such a site has to be used, it must be completely covered with a thick layer of impervious concrete or asphalte.

(3) The relation of the area of the site to the number of beds is very varied in different countries. Naturally for hospitals without upper stories a greater proportionate area of land should be provided. In large towns the site must be more restricted than in small centres where land within reasonable distance and at a moderate cost will be probably available. About 1,000 to 1,800 square feet of site per bed may be considered limits below which it is not desirable to go, nor, on the other hand, necessary to exceed.

(4) In India the cost of the site for a hospital is not one which, except in very large towns, will bias decisions as to the most suitable locality, and, at any rate, it is a question which must be decided with reference to each particular town.

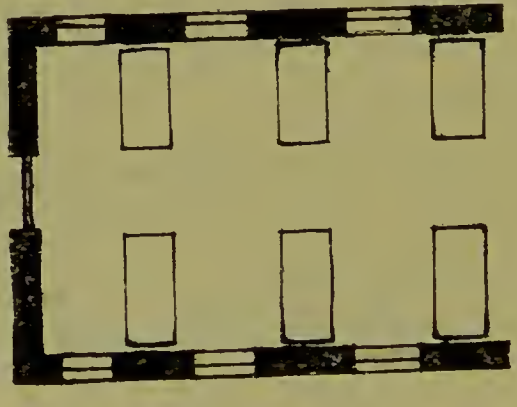
Number of beds in reference to population.—Before the minimum area of site required can be determined, it is necessary to determine the number of beds which the hospital has to maintain, and the following table shows the relationship in reference to population in certain towns in England :—

Table showing the proportion of In-patients to population, the total number of Hospital beds available and the number of Hospital beds per thousand of the population.

Number.	Name of town.	Population.	In-patients.		Beds.	
			Total number.	Number per 1,000 of population.	Total number.	Number per 1,000 of population.
1	Dublin	353,082	16,236	45·9	2,256	6·39
2	Edinburgh ...	261,970	10,075	38·4	996	3·80
3	Glasgow	567,143	16,501	29·1	1,953	3·44
4	Aberdeen ...	121,905	2,920	23·9	324	2·65
5	Leicester ...	142,581	3,000	21·0	240	1·68
6	Norwich	101,316	1,716	16·9	266	2·62
7	Leeds	369,090	5,677	15·4	504	1·36
8	Sunderland ...	131,302	1,890	14·3	275	2·09
9	Derby	94,496	1,299	13·7	216	2·28
10	Huddersfield ...	95,656	1,034	10·8	178	1·86
11	Halifax	83,109	867	10·4	132	1·59
12	Birkenhead ...	99,597	1,028	10·3	171	1·71
13	Cardiff	130,283	1,236	9·4	120	0·92
14	Portsmouth ...	160,128	1,052	6·5	103	0·64

It will be seen that one town has as high as 6·39 beds per 1,000 of population and one as low as 0·64 per 1,000 of population, a very large difference. The majority of towns have between one and three beds per 1,000 people. For Madras hospitals, it is proposed that the standard of one bed per 1,000 of population should be adopted. This is a comparatively low requirement. It must be remembered, however, that large numbers of the population will not resort to hospitals as freely as similar classes in England do. The population to be regarded in reference to up-country towns must include that of all the neighbouring villages not supplied with hospitals, say, within a radius of 10 or even 20 miles. Besides the above accommodation, special hospitals are required for special diseases, such as cholera, small-pox, &c. Too often is the provision for these actually delayed until some infectious disease appears; but all towns and villages ought to be provided with such hospitals to accommodate at any rate the first infectious cases appearing.

Hospital wards may be of various forms, such as the corridor ward ventilated on one side only, the double ward, the cross-ventilated single ward, &c. The corridor cross-ventilated single ward is the plan most generally adopted and is that shown in the following diagram :—



Each bed in a ward should have a window on either side of it, or rather there should be one bed, only between each pair of windows or the beds may be what is called 'couplod,' that is, there may be two beds between each pair of windows, but this is not so good a plan as the former. Wards of over 20 beds should have a breadth of 28 feet and with a less number may have 22 to 24 feet. Each bed should have a floor area of

100 square feet and a wall space of 7 feet 2 inches to 9 feet (according to the breadth of the ward). The height of a ward should not be less than 14 feet. This, with a floor space of 100 square feet, would give 1,400 cubic feet; no height over 14 feet is to be taken into consideration in calculating the cubic air space per bed.

Hospitals for infectious diseases.—Large villages and groups of villages may be served by one hospital, and the accommodation required will not differ much from that required in towns. Diseases, such as cholera and small-pox, are generally prevalent for a comparatively short time only, but during that time, of course, the number of cases is comparatively great. Thus the accommodation required should be decided on past experience rather than with reference to any particular proportion of the population.

In towns, these hospitals are more constantly required than in villages, and therefore more permanent structures are desirable.

Site for hospitals for infectious diseases.—Such hospitals require a larger space about them than ordinary hospitals, and they should be placed as far outside a village as considerations of accessibility permit. In determining the locality for a hospital for infectious diseases, the wholesomeness of the site, the character of the approaches, the facilities for water-supply and for slop and refuse removal are matters of primary importance.

Isolation hospitals.—The wall space in isolation hospital wards should not be less than 12 square feet per bed. The superficial area should be not less than 144 feet and the cubic space less than 2,000 feet per bed in permanent buildings. As a rule, semi-permanent or even temporary buildings are more suitable for such purposes, and in them the wall space may be 9 feet, the superficial area 100 feet, and the cubic space 1,800 feet per bed. In smaller towns, say, under 5,000 inhabitants, this should be arranged for permanently in connection with the civil hospital by the provision of separate huts with two beds for males, and two for females, for cholera, and small-pox cases. In larger towns there should be separate hospitals well removed from the centres of population, in as open a space as possible, with no ward nearer the boundary than 40 feet. Such a hospital should be provided with permanent administrative and subsidiary buildings and temporary huts

for the sick with an observation hut for each sex and each disease. There should only be sufficient beds for cholera cases to deal with the class of patients who have no habitation of their own or where the private accommodation is quite inadequate. As a rule, cholera cases will require to be treated in their own houses, but separate arrangements should be made for housing the unaffected inhabitants of infected houses. In isolation hospitals, there must be a separate subordinate medical staff and the necessary establishment for the care of the patients.

Lying-in hospital.—It is desirable to have this quite separate and with an establishment separate from the ordinary hospital. It must be situated near the centre of the population which will use it. It should have an ample area not more than 35 to 45 beds to an acre. There should never be more than four beds in a ward, which means eight patients including the infants; the floor and air space should be calculated as for an isolation hospital. There should not be more than eight beds in one ward unit, consisting of not more than two wards; there should be two separate delivery wards for each ward unit, one to be under cleaning and one in use; there should be a bath-room or scullery to each, with plenty of water and means for disinfecting soiled clothing; there should be a separate compartment for cleaning bed-pans; the floor space in these delivery wards should not be less than 200 square feet, and the floors should be on the same level as those of the wards; they should be joined by an open-covered passage to the lying-in wards. It is a good plan to have a by-ward in connection with the delivery ward for the temporary care of specially exhausted cases. In the lying-in wards the scullery and latrine should be under a separate roof and joined by a covered passage with open sides; the bath-room may be in the corner of the verandah and should be supplied with a bath on wheels; the attendant's room and the store room may also be in the verandah corners.

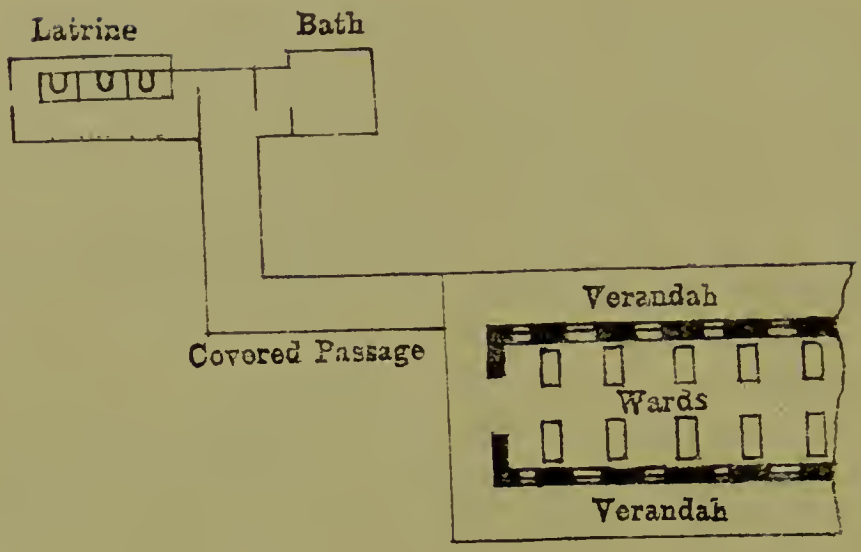
Dispensaries.—Where there is an out-patient department attached to a hospital, the dispensary should be as near to the entrance to the hospital enclosure as possible, but have a separate entrance of its own and isolated from the hospital enclosure. There are, of course, many dispensaries throughout India not attached to any hospital, and these should be placed as near the centres of population as possible, the requirements regarding air, space, &c., not being so necessary.

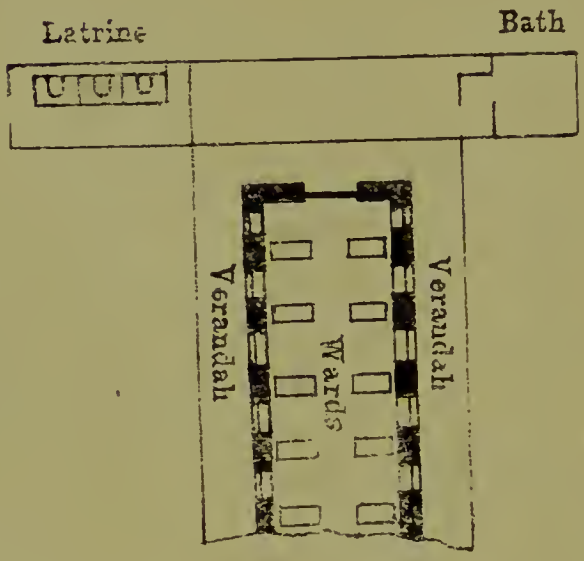
A dispensary should be thoroughly well ventilated and there should be plenty of light everywhere. There should be separate waiting rooms or verandahs for each sex, separate dressing rooms and separate windows for distributing medicines. There should be a consulting room with a small examination and operation room for each medical man prescribing. There should be a well-fitted dispensing room. The walls of floors should be the same as those hereafter prescribed for wards.

Ventilation.—The ordinary ridge and eaves ventilation in India will be sufficient for smaller-sized wards on the plains. In cold climates, where doors and windows must be shut at nights, ventilation must be arranged for by means of short flues through the wall at the floor level or by Tobin's tubes for the inlet of air and by means of flues passing into the chimney or through the roof or walls to independent outlets. In very large hospitals on the hills, some mechanical means may be found necessary. The windows and doors in all wards should be opposite to one another. Windows in permanent wards should extend from within 2 feet 6 inches of the floor to a height 2 feet below the eaves and should have a combined area of not less than 1 foot to each 40 feet of floor space. The design of the windows recommended is that suggested by the Indian Barracks Commission. Doors of wards, operating, examining and out-patient rooms should not be less than 4 feet 6 inches wide. There should not be less than four in any ward, one at each end and one at each side.

Hospital latrines.—The ward latrine should be separated from the ward building; it should be on the same level and connected by a covered passage with open sides not less than 6 feet in length; there should be one seat for each five patients; the seats should be separated by partitions. They should be as well ventilated and lighted as possible allowing for their necessary privacy; the roofs may be of corrugated iron on iron posts.

The basement and floor must be so arranged that there will be no chance of urine or sullage water soaking into them or running over the adjacent ground. There should be a room for the sweeper, a place for an iron filth receptacle (when the water system is not in use), and a small room to keep bedpans or excreta which has to be inspected. In this room also there should be a tub in which soiled clothing could be steeped in disinfectants. In latrines for natives there should be the usual arrangements for ablution.





Bath-rooms.—There should be a bath and ablution room in one corner of the ward verandah which should be supplied with a bath on wheels. There should be a small stove for heating water or a hot-water apparatus as used in military hospitals. The mode in which latrines and bath-rooms are disconnected from the wards is shown in the preceding diagrams.

Foundations, &c.—The basements should, if possible, be arched or otherwise raised so as to secure an air space in damp climates never less than 3 feet high. In malarious climates, it is better to have the ward floors at least 10 feet from the ground. In semi-permanent buildings for cottage and hut hospitals, the permanent basement should not be less

than 1 foot high in dry and warm climates. It should be filled in with clean gravel and covered with not less than 6 inches of concrete throughout.

Walls.—Those of permanent buildings should be made as smooth and as impervious as possible; their junction with the floors and at the eaves should be slightly curved with a radius of not less than 2 inches, the concavity being towards the interior. No cornices or raised work of any character should be allowed. A damp proof course should be laid in all permanent walls. The walls up to 5 feet 6 inches high may be of white-glazed bricks or covered with Portland cement painted and varnished, or glazed tiles with a suitable border. The upper portion of the walls, the roofs and the ceiling may be coloured in *light tints* of silicated paint, colour-washed, or even white-washed according to funds at disposal.

Roofs should be of a pattern not offering surfaces for the lodgment of dust, hence roofs might be built arched with iron tie-rods after the manner successfully adopted by Mr. Stoney, Civil Engineer, Madras Railway.

Drainage.—There should be ample surface drains to carry off all storm water with rapidity. The disposal of sewage and sullage water must vary with the means at command. If the town possesses a pipe drainage system, the hospital drainage should be connected with it. If not, one of the various modes suitable for single establishments by ventilated and trapped cesspools for temporary storage and disposal direct to land for irrigation with or without precipitation, according to the distance from the wards site, should be employed. If the expense of carrying sewage to a suitable site for disposal by pipes be prohibitive, urine and latrine washings should be received, and fæcal matter be collected in the latrines separately; the former in covered wells, the latter in well-tarred iron receptacles; both should be removed in Crowley or other suitable carts at least once a day from the hospital and disposed of as similar sewage is from the rest of the town, or, if possible, the sewage should undergo precipitation and be disposed of by filtration through under-drained land; the sludge and fæcal matter should be burnt in a special form of cinerator and the ashes used as manure in the garden. In every hospital enclosure there should be a small simple cinerator for burning rubbish, and the ashes should be used as manure.

Water-supply.—Water-supply should be ample in quantity and as pure as possible. If from wells they must be well protected with good parapet walls and provided with roofs,

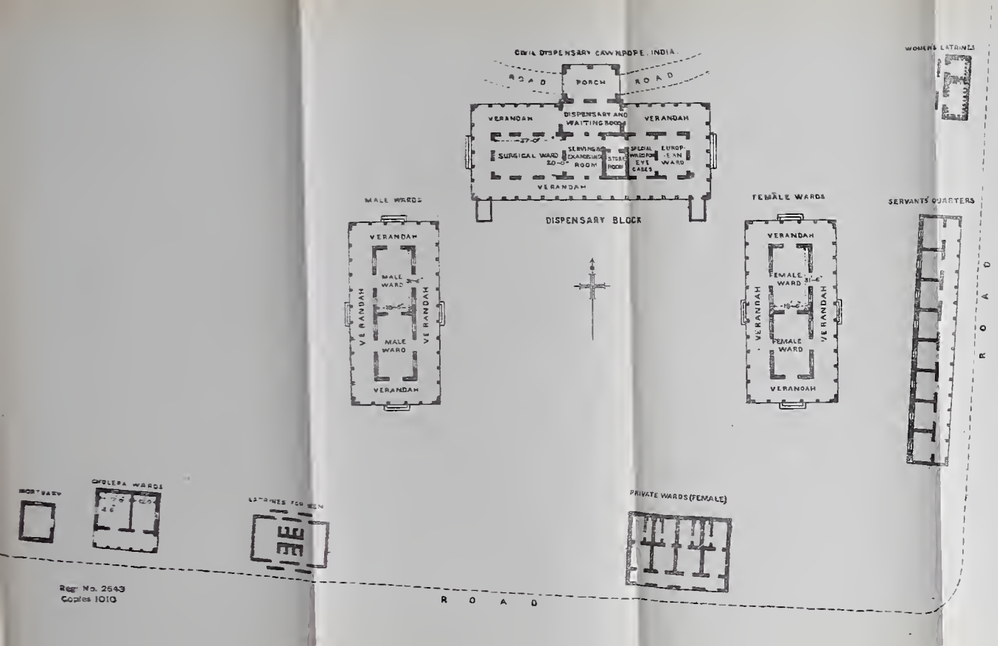
pumps, closed cisterns with a tap, and an encircling platform. When there is no public water-supply, the addition of a tower to the administrative blocks served by a force pump would facilitate the distribution of water under pressure, which should certainly be arranged for at every part where water is required, such as the kitchen, latrines, operating room, bath-rooms, dispensary room, *post-mortem* room, laundry, out-patients' department, &c.

Semi-permanent buildings for cottage and hut hospitals.—In warm climates such as the Madras Presidency, walls are scarcely required in wards; tatty bamboo mats on wooden frames do excellently well and can be smeared with mud in cold climates or they may be painted; a good plan is to have them hung on wire frames instead of wood. The verandahs should be broad enough to protect the mat walls from the sun or beating rain.

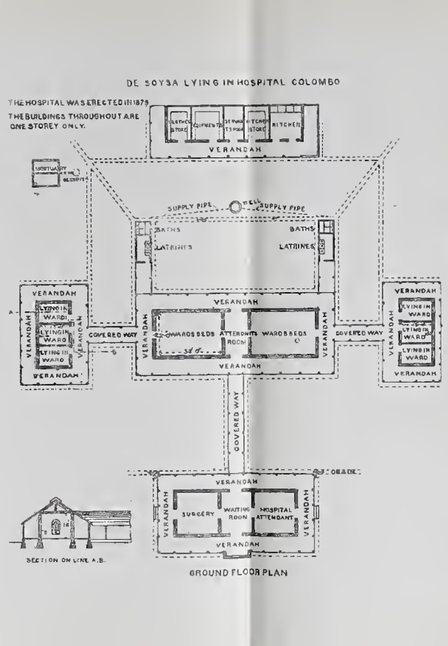
Designs of hospitals.—The accompanying plate includes designs of several hospitals in India and certain type designs proposed for minor towns in the Madras Presidency.

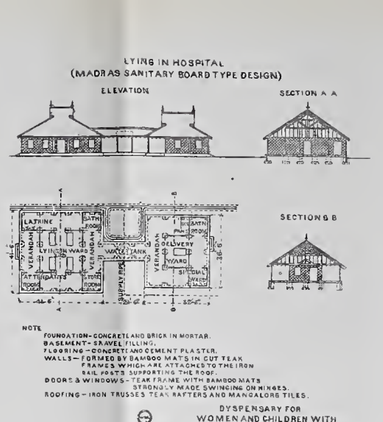
For no two hospitals will the same design be suitable; but the grouping of the wards and offices should always be such that—

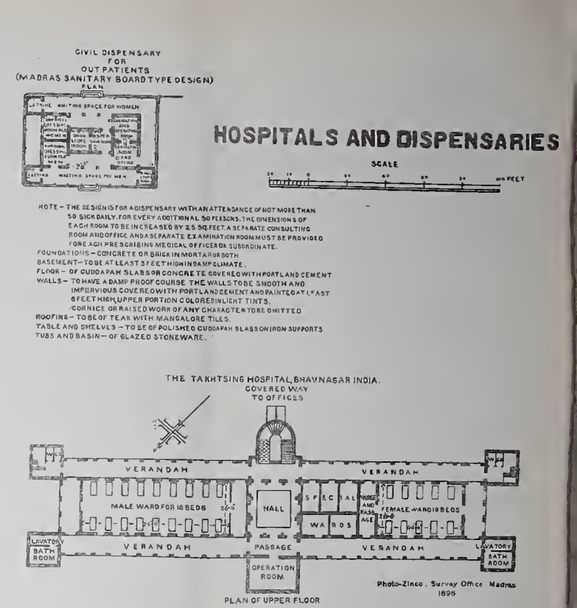
(1) there is free circulation of air around and between each ward pavilion;
(2) the spaces between each are well exposed to sunshine;
(3) the distance between each is twice the height of the pavilion reckoned from the floors of the ground floor ward to the eaves if a very sloping roof, or to half the height of the roof if a steep roof;
(4) the administrative block, kitchen and store buildings are placed as central as possible, the ward pavilions for general diseases, medical and surgical for each sex, being on either side. These buildings should be all joined together by covered passages open at the sides, especially in wet climates;
(5) the special wards should be situated to the rear of these;
(6) the servants' quarters should be still further back, the laundry at one corner to the rear and the mortuary and *post-mortem* room with a separate exit from the enclosure at the other corner;
(7) the out-patients' department should be as near the entrance to the hospital enclosure as possible and have a separate entrance of its own and should be isolated from the general enclosure. The ambulance shed should be either in it or close to it;



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(8) the enclosure should be protected by either a dwarf-pierced wall or by railings with only three gates —one for the hospital, one for the out-patients' department and one exit from the mortuary.

The following statement shows the cost of certain hospitals and also the amount per bed :—

Name and description of hospitals.	Number of beds.	Cost per bed.			Total cost.		
		RS.	A.	P.	RS.	A.	P.
Madras Government Lying-in Hospital.—The cost including the present superintendent's quarters, matron's and nurses' quarters, steward's store-room, medical subordinates' quarters and all buildings of a permanent character.	136	2,277	13	4	3,09,785	0	0
Madras Government Ophthalmic Hospital.—The cost of the construction of the hospital, subsidiary buildings, out-patients' department and medical subordinates' quarters. all permanent buildings exclusive of site.	76	1,872	3	2	1,42,287	0	0
Caste and Gosha Hospital, Madras.—The cost including the hospital, subsidiary buildings, medical officers' quarters, all permanent buildings exclusive of site.	64	1,562	8	0	1,00,000	0	0
Government General Hospital, Madras, special semi-permanent isolation wards.—The approximate cost of these wards with a nurse's room, two store-rooms and a kitchen exclusive of site.	41	463	6	8	19,000	0	0
One of the surgical isolation hut wards in the same hospital without any subsidiary buildings.	10	300	0	0	3,000	0	0
Bellary Lying-in Hospital.—Opened in 1894 of a permanent character with subsidiary buildings and hospital assistants' quarters.	8	968	12	0	7,750	0	0
Bellary Police Hospital.—Opened in 1893 ; wards and subsidiary buildings, all permanent.	17	497	5	0	8,454	5	3
Nellore Jubiloe Lying-in Hospital.—With wards, matron's quarters all of a permanent nature exclusive of site.	21	994	8	4	20,885	0	0
Tanjore Rajah Mirasidar's Hospital.—Buildings of a permanent character, pavilion wards, subsidiary buildings, administration block, and out-patients' department and quarters for medical subordinates.	120	567	14	5	68,148	6	3

CHAPTER VII.

WATER-SUPPLY.

COLLECTION.

In a previous chapter the various sources from which water can be obtained have been detailed, all these sources, nevertheless, depending on one original source, viz., rain ; the several modes of making the rainfall available are—

(1) *Direct collection.*—The rain, as it falls, is stored in suitable receptacles close to the place where it is required.

(2) *Wells and springs.*—The water may be drawn from the store contained in the underlying strata by sinking wells, or, collected at certain places where it issues in the form of springs.

(3) *Gathering grounds.*—An area of land is chosen, and the rain falling thereon is collected and stored, and thence distributed in pipes or conduits.

(4) *Rivers and streams.*—Water is taken from a river or stream by pumping, by branch channels or otherwise.

Cisterns, wells, &c.—The first and second methods are those by which the great bulk of the population in India obtain their supplies. In the first method the water is collected in cisterns, tanks, &c. This system obtains where the monsoon rainfall is heavy ; it is a system suitable for isolated buildings, such as jails, asylums, institutions, &c. Or the rain is collected from local areas in large tanks ; these are a feature in Southern India. Where wells are used they are usually shallow, drawing their supplies from a limited area.

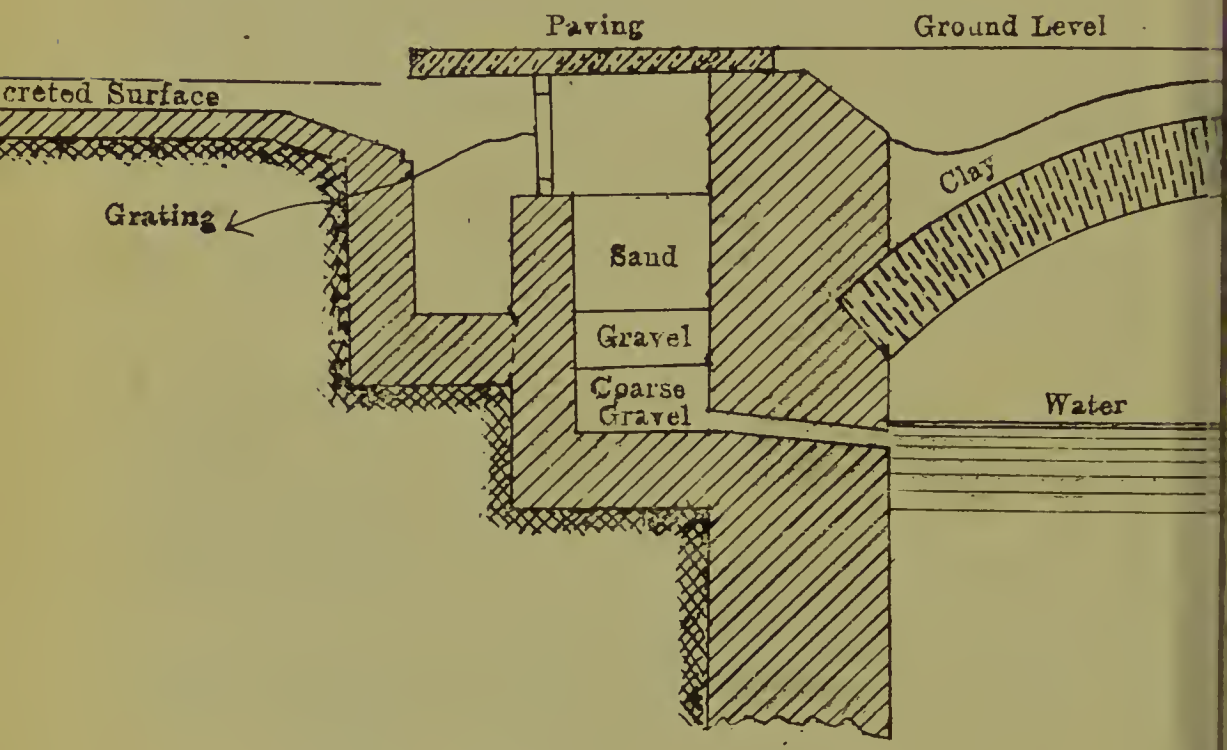
Tanks.—The third of the methods mentioned is also one which finds application on a large scale, in India, chiefly for irrigation purposes. Only such tanks as can be depended on to store a supply sufficient for more than a year's consumption are suitable for use in connection with a town's water-supply. The water under this mode is collected from an area of land on which a fairly large quantity of rain usually falls ; such areas for town water-supplies must be fairly free from pollution and should be uninhabited. By reason of the slope of the ground, by existing streams or by channels formed in the ground the water is conveyed to a valley where an embankment is raised and the water dammed back, thus forming a tank or reservoir. For a town's supply a conduit or pipe carries the water from the reservoir to the town where the supply is required ; if the tank is an irrigation one, ordinary open channels distribute the supply. The formation of large reservoirs of this kind is a responsible and difficult matter only to be undertaken under competent advice. The first object is to secure the safety of the dam and to make it perfectly water-tight. Natural lakes may also be used for town supplies, but any lake so used must have its surface level considerably raised so that it may be drawn down for use on occasions of short rainfall.

River supplies.—The fourth method of obtaining a supply is by drawing water from rivers ; in India this source, unless the river is very large, is not a very certain one ; but in many of the larger rivers, it is found, that although in the hot season there is no flow above the bed, there is a flow through and under the sandy bed of the river, and this source of supply is one that is often selected.

The proper methods of dealing with each of these modes of collection now become the subject of description.

Small tanks and impervious areas.—Where these are iron or masonry tanks, or cisterns filled from roofs, or from paved or cemented surfaces, great care must be exercised to see that the surfaces are kept perfectly clean. This, with large amounts of impurities in the air as well as on the collecting surfaces, is practically impossible, and filtration must therefore be resorted to before any water so collected is used. Unless the rainfall is fairly regular, very large tanks or storage reservoirs are required. The system, however, is one which it is sometimes necessary to adopt and is suitable for jails, schools and other isolated buildings. For hospitals

the system is not advisable, owing to the air impurities which are necessarily large in their immediate surroundings. In making concreted and cemented surfaces for the collection of rain water, these should be laid on the ridge and furrow system, the whole surface being also laid with a slope towards a collecting drain. The collecting area and the storage tanks should be placed, if possible, on ground elevated above the point where the supply is required or extra expenditure in raising the water for use is incurred. The water from the collecting drain should be passed through, at least a strainer if not a filter, and collected in a covered reservoir for use. Such an arrangement is shown in the accompanying diagram :—



Where there are long periods of drought, if the tanks or cisterns are the only means of supply, they must be large enough to contain the quantity of water required, say between one set of rains and another. The gathering area must have sufficient surface to collect the quantity thus required during each period of rainfall.

Suppose the conditions of average rainfall are as shown in the following table :—

Months.	Fall in inches.	Number of persons to be supplied.	Amount per head daily.
January	0	1,000	Say 2 gallons. (This is for dietetic purposes only).
February	2		
March	*Nil.*		
April	*Nil.*		
May	2		
June	10		
July	15		
August	10		
September	8		
October	0		
November	*Nil.*		
December	1		

The supply required during the year is $2 \times 1{,}000 \times 365 = 730{,}000$ gallons. The monsoon rainfall alone need be considered, that is between May and September during which 45″ of rain falls. Each square foot of area per 1″ of rain will yield one-twelfth of a cubic foot and 45″ will yield $3\frac{3}{4}$ cubic feet or 23·43 gallons. The area required is therefore $\frac{730{,}000}{23{\cdot}43}$ or 31,156 square feet. To allow for dry years double this area would be advisable. With the rainfall distributed as noted it would be well to allow for storage for not less than 8 months, the rainfall during the month of May yielding less than the monthly demand, viz., $\frac{4}{1}\frac{5}{2}$″, but in case of the area being doubled as above suggested, storage for seven months might be sufficient; it is, however, desirable to provide storage 50 per cent. at least in excess of the average demand. The more exact methods of determining the size of gathering grounds and collecting tanks are dealt with in a later portion of this chapter.

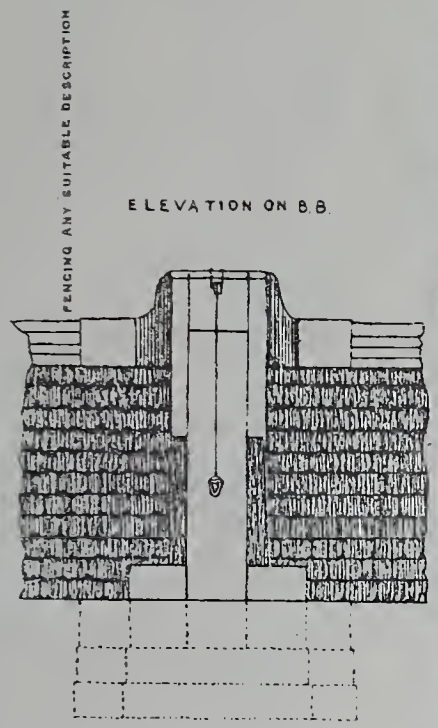
The system of collecting areas and storage tanks cannot be made applicable to places with limited or unfrequent falls of rain, nor to large populations, the expense being considerable.

The following table shows the actual area required to supply the number of persons noted with one gallon daily per annum for various depths of rainfall; if the depth assumed is the average rainfall the collecting area ought to be increased by 50 per cent. over the area given:—

Number of persons.	Supply required in gallons per annum (1 gallon per head daily).	Supply required in cubic feet per annum.	Inches of rainfall.				
			5″	10″	20″	30″	Approximate size of area for 30″ rainfall.
			Square feet of area required.				
50	18,250	2,920	7,008	3,504	1,752	1,168	34 × 34
100	36,500	5,840	14,016	7,008	3,504	2,336	48 × 48
500	182,500	29,200	70,080	35,040	17,520	11,680	108 × 108
1,000	365,000	58,400	140,160	70,080	35,040	23,360	150 × 150
3,000	1,095,000	175,200	420,480	210,240	105,120	70,080	265 × 265
5,000	1,825,000	292,000	700,800	350,400	175,200	116,800	342 × 342
10,000	3,650,000	584,000	1,401,600	700,800	350,400	233,600	483 × 483

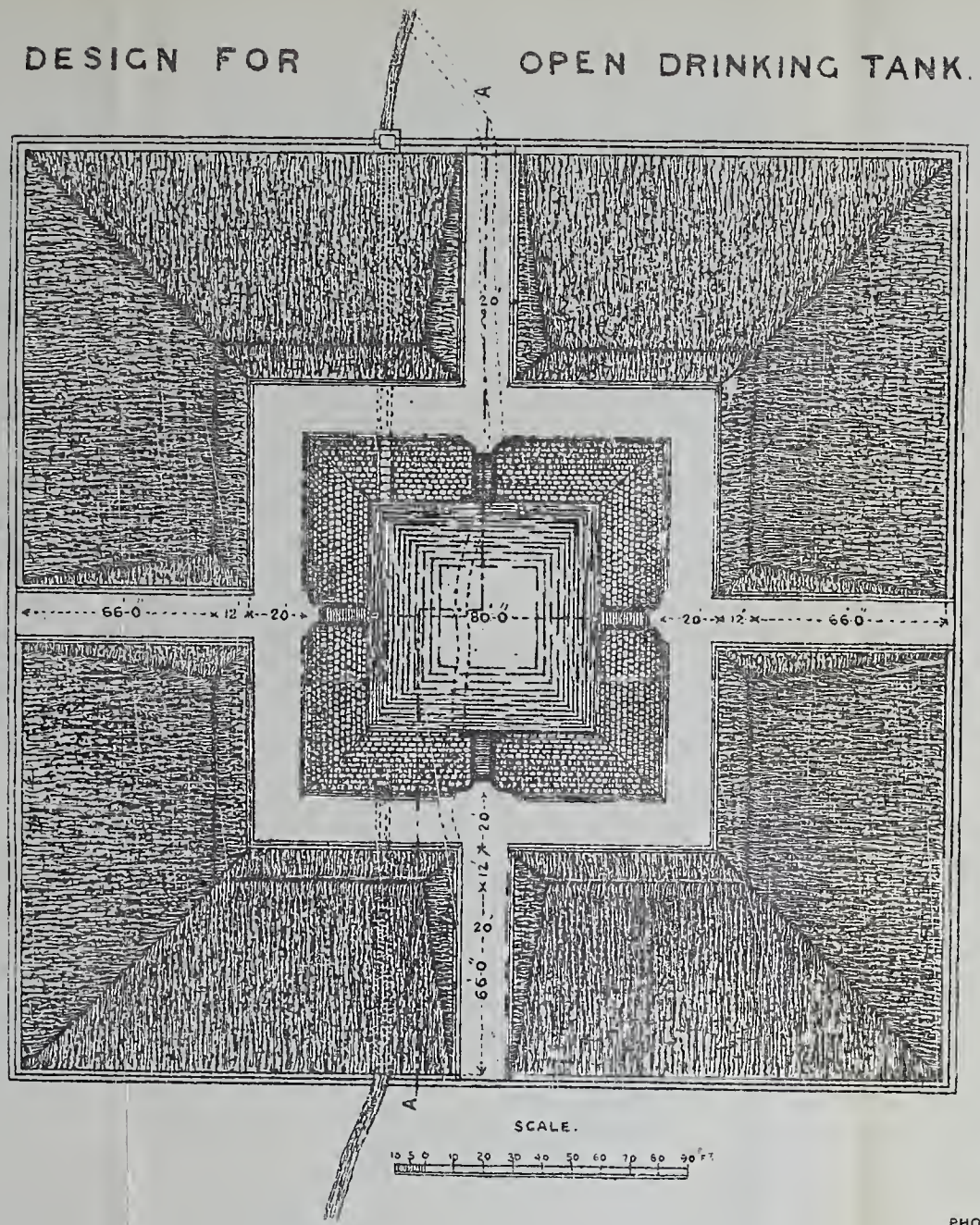
If the receiving floor is not perfectly impervious, a deduction for absorption will be required. About $\frac{1}{4}$″ depth per diem over the area of any *exposed* surface of the receiving tank must be deducted for evaporation; when the tank is covered the amount of evaporation from it will be comparatively little.

DESIGN FOR OPEN DRINKING TANK.



NOTE

ONE OF THE WELLS SHOULD BE 4 FEET DEEPER THAN THE OTHERS TO FACILITATE EMPTYING THE TANK WHEN NECESSARY.





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Iron tanks must necessarily be of limited capacity and it is desirable to point out that, in estimating the collection of rainfall, only the flat space covered by a roof must be taken into account.

Tanks.—The word 'tank' in India has a wider meaning than that ordinarily given to it elsewhere, and includes artificial lakes whether filled by (1) local rainfall or by (2) rainfall on areas at considerable distances: it is to the former class (1) that attention is now directed. In every village are found numerous tanks used, very often if not always, for all purposes indiscriminately. Drinking, washing, bathing go on side by side and water is often carried home for domestic, if not dietetic, purposes. These tanks are filled during monsoon periods from surfaces usually badly conserved and much polluted. Their supplies are often supplemented by springs within their banks, but the water as received into the tank is far from fit for drinking or even washing. Drinking-water tanks, under existing conditions in most Indian towns and villages, are a necessity, though they must always be an unsatisfactory source of supply. Such tanks must be within easy reach of the population and thus they are extremely difficult to conserve. In forming new drinking tanks, the site selected should not be adjacent to other tanks, cesspools, or hollows whence percolation may take place. The site should, of course, be lower than the surrounding area which should be entirely free from pollution and kept so. The earth excavated from a new tank should be placed round the margin of the tank and used also for filling up hollow places within the conserved area. Channels ought to be formed round the tank and the water carried into the tank by built drains. No rainfall should be allowed to flow down the banks of the tank except that falling directly on them. The slopes and bottom of the tank should be puddled, if the supply is to be received from gathering ground only, but if it is also to come from the bottom of the tank, sand three feet in depth may be substituted for puddle. No approach to the waters of a drinking tank ought to be permitted. All water should be drawn from wells sunk in its bed and by a pump or pulley and rope arrangement. A tank such as described is illustrated on the plate accompanying.

Plants and fish in tanks advisable.—In all tanks and reservoirs, water plants and fish in moderate quantities are a necessity; the former improve the chemical condition of the water, the latter keep down the number of insects,

crustacea, &c. All dead vegetation ought, however, to be speedily removed from a tank and its margin.

Capacity of tanks.—The proper capacity of an open storage tank, dependent for its supply on the rainfall, is not easy to determine. It should be capable of containing at least twelve months' supply, and perhaps five gallons per head is sufficient or more than sufficient for ordinary dietetic purposes. When speaking of the collection of water from impervious areas and its storage, calculations were made which will show the basis from which these must start, but further elements enter into the question of open tanks with pervious collecting areas. The percentage of the rainfall received into the tank will not exceed on an average 33 per cent. of the total fall. The loss in the tank from soakage and evaporation has also to be considered; for ordinary soils, neither porous nor very clayey, the total of these two losses may be taken to average six feet per annum. A limited supply, say, two gallons per head for drinking only, stored in a properly-protected and covered tank, is preferable to a larger supply more liable to pollution.

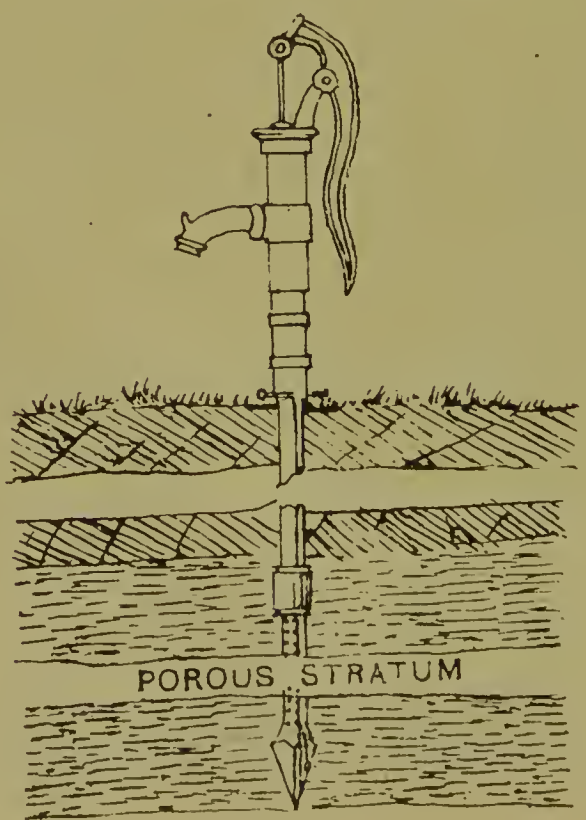
Conservancy of tanks.—Existing tanks for drinking purposes require careful watching, and they should be improved as far as possible in the direction indicated by the foregoing remarks. All drinking-water tanks should be bunded round and fenced and all direct approach to the water shut off; adjacent drains, cesspools, &c., should be diverted into impervious channels, closed, or otherwise dealt with. The gathering area of a tank should be carefully protected from pollution and every opportunity should be taken to clear away decaying vegetation and other impurities from the tank. When access to the waters of a tank is shut off, there must be some means of making the water readily available. This can be done by wells sunk in the slopes of the tank, but the plan of building cisterns outside the protecting fence and filling these as required by water drawn from the tank by a pump is preferable. The pump may be a hand-pump or some lift worked by cattle or by a windmill. The cisterns should have taps provided; the dipping of each consumer's lotah into the water-supply is objectionable in every way.

Wells.—Wells and springs are an important source of supply throughout the world; there is, however, a marked distinction between the waters received from shallow, deep or artesian wells; unfortunately it is from the former class of

well that the bulk of the people in India derive their water-supply. An ideal well is one where the water is drawn through a water-tight tube from a deep stratum into which the water must have filtered through suitable soil, which well is covered and thus free from all pollution. The ordinary village well of India is usually shallow, drawing its supply from surface strata; it is usually lined with brick in clay or other pervious material, sometimes with no lining at all; bats, snakes, rats often abide within it. It is frequently shaded by trees, from which it receives the decaying vegetation; their roots penetrate the sides of the well and lend an easy passage for the carriage of the pollutions which generally surround it. All surface strata must be more or less contaminated and adjacent to buildings, especially isolated ones, there must be cesspools or similar receptacles, the contents of which are very likely to be drawn towards, and to contaminate the well. The more a well is drawn down the greater will be the distance from which its supply is derived, because the surface of the water supplying the well must have an inclination to give it the necessary head to overcome the friction in the interstices through which it flows. A conical depression is thus produced all round the well, and, as the surface of the water in the well is lowered, the area of the cone of depression extends further and further around it until it reaches a considerable distance. The distance varies not only with reference to the decrease of level, but also to the porosity of the strata from which the water is drawn. The more porous the ground is, the greater is the base of the cone of depression (the apex of the cone being at the bottom of the well) for any particular depth of well; the greater the density of the strata the steeper is the incline assumed by the sides of the water cone. The water in wells is contaminated not only by matters in the soil, but it receives impurities such as dust, leaves and other matters blown into it. Floods will also wash organic and inorganic impurities into it; dirty vessels used for drawing water pollute it and the washing of the person or clothes close to a well is highly injurious. Wells, therefore, ought to be sunk in areas as free from pollution as possible and to a considerable depth. A well ought to be water-tight except in its lower portion and be protected all round by a parapet wall. The water ought to be drawn by a fixed pulley and bucket. Arrangements should be made for carrying away waste water falling on the surface near the well. No well ought to be sunk less than 5 feet below the lowest known water level. Wells should be covered in by a roof if the pulley and bucket system is used. It is a preferable plan to cover in

a well at a lower level (slightly above ground) and to place a pump on it and pump the water into cisterns in which taps should be fixed. Sketches of wells, constructed on the pulley and bucket system, are shown on the accompanying plate. Shallow drinking-water wells ought not to be placed near burial grounds, slaughter-houses, tanneries, cesspools or sewers; they should be as far as possible from dwelling houses, from cultivated fields, tanks and other places where animals or clothes are washed. A class of shallow wells, to which reference will be made in a later portion of this chapter, is that used in water-supply works and sunk in the sandy bed of rivers; where the rivers are broad, the supply ample, and population at some distance from their site, they are not open to most of the pollutions enumerated above.

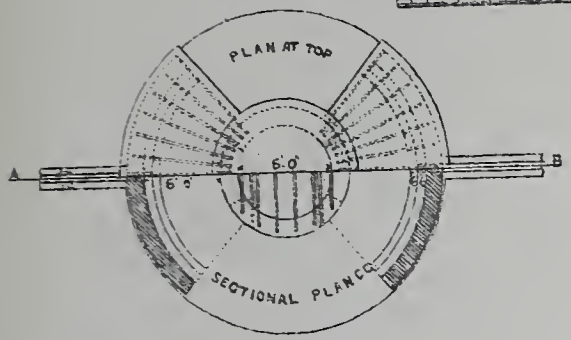
Tube wells.—Abyssinian or tube wells, as illustrated, are a useful class of wells, especially for temporary use; they consist of a tube of small diameter which is driven into the ground by means of a pulley and falling weight, fixed on the length of the tube extending above the surface; the lower end has a steel point, and the tube just above this point is pierced with holes through which the water passes. When the well has been driven to the required depth, a pump is fixed on the top of the tube and any water available obtained. These wells are useful in light and sandy soils highly charged with water at such places as small villages, isolated houses, camps, &c.



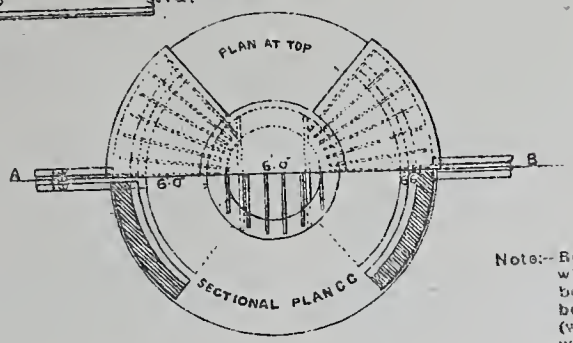
DESIGN FOR WELLS

SUNK WELL

SCALE 0 5 10 20 30 Feet



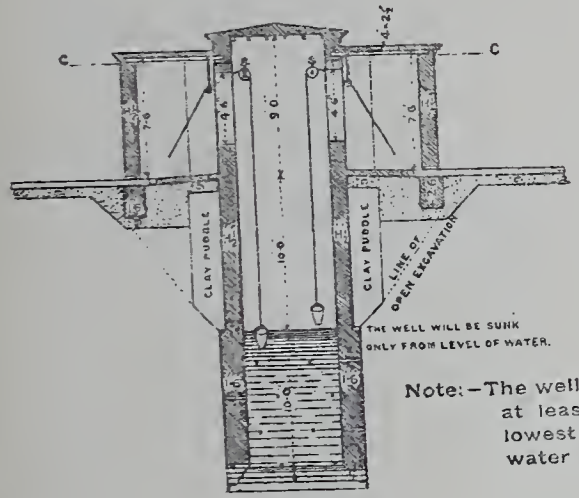
BUILT WELL



Note:—Built wells can only be adopted where infiltration is slow. This being the case, the cheapest and best method of construction (when excavation has reached water-level) is to work night and day on the excavation below water-level, and start at once building dry masonry to water-level. Using mortar or mud in this length is worse than useless as it would be washed out if any baling became necessary, whilst building this length.

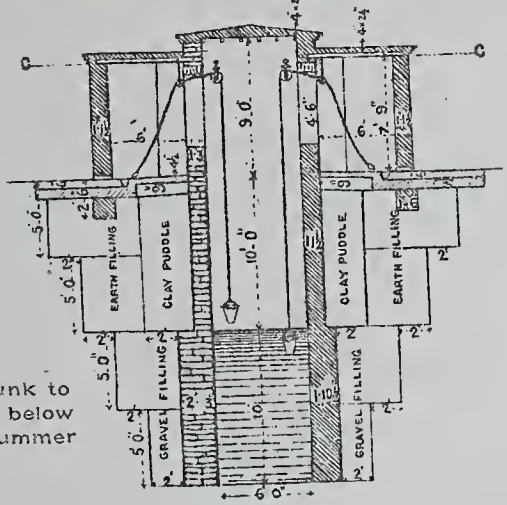
The outside roof and floor should not be built till the earth-filling is thoroughly consolidated. Damping the earth when filling will hasten consolidation.

SECTION ON A.B



Note:—The well should be sunk to at least five feet below lowest known summer water level.

SECTION ON A.B.



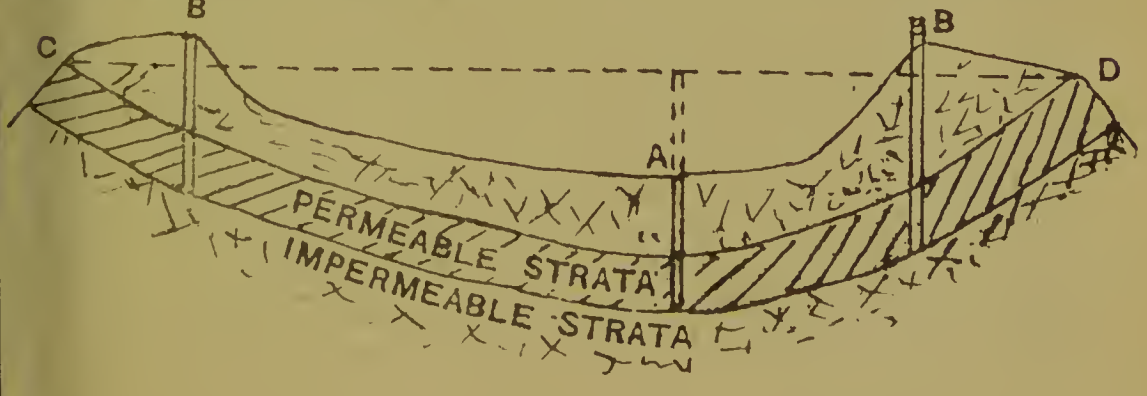
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1995

Where ground is very porous holding large quantites of water within 20 or 25 feet of the surface, a large number of tube wells, formed by driving into the ground steel or iron tubes 6″ to 12″ in diameter or larger, may be sunk and these all connected to a central tube over which a pump is placed. In several places such a system is in use, but care must be taken to place the wells so far apart that, when pumping, the supply from one well does not reduce that from another.

Deep wells.—Deep wells drawing their supply from strata lying low in the earth are in a different category from the wells mentioned above and any impurities in their waters are usually inorganic. There are two classes of deep wells, those in which a shaft is sunk into a water bearing stratum where water lies at a low level and which is then pumped up to the surface, and those where the water naturally rises to or near the surface or above the local subsoil water level. The latter are called artesian wells. From the former class adits are sometimes driven in various directions from the bottom of the well so as to enlarge the area of collection. These are made to follow, as far as possible, the line of fissures in the rock from which the water is being obtained.

Artesian wells.—Artesian wells are a valuable source of artificial supply of water; as to the supply to these wells the theory is this, *viz.*, that water descending through a permeable stratum of the earth and reaching either a cavity or a bed of spongy or porous material will accumulate there, if its egress is prevented by an impervious surrounding stratum; then, if an artificial opening or well be made into this water-bearing bed, the water will rise upward to a height due to the superior elevation of the source. These wells are called artesian, having been long adopted in Artois in France. A well of this kind will deliver water above ground if its source is sufficiently high; thus, in the following sketch the water in well A would rise above ground, whereas at B, it would only rise to a level somewhat less than the height of the line C D.

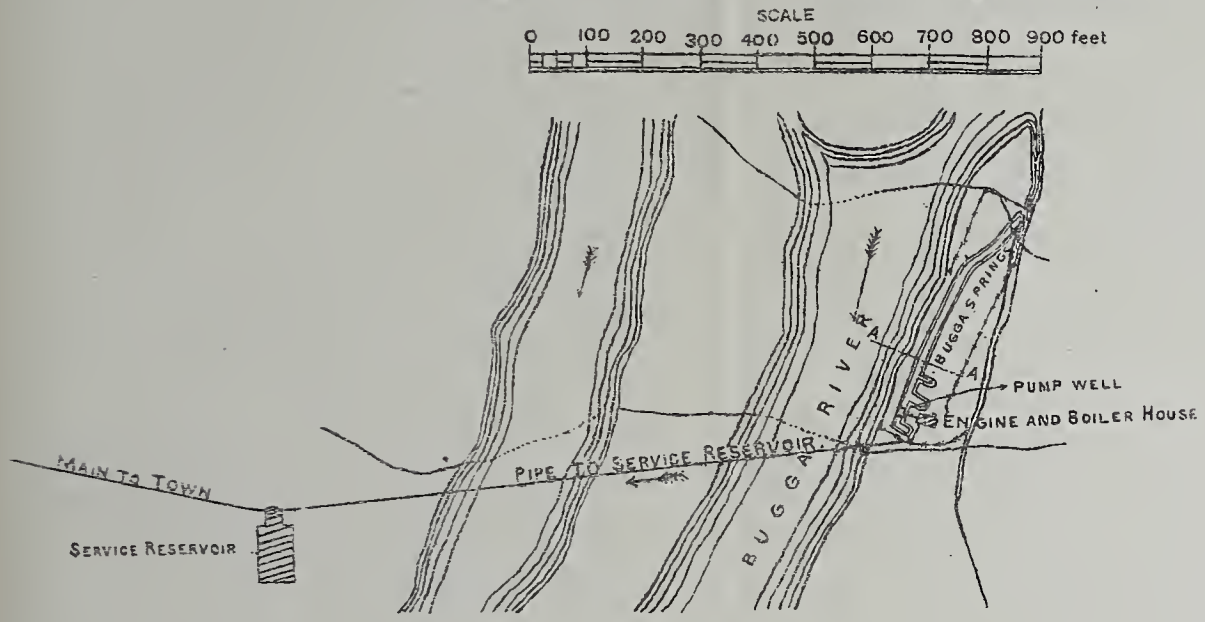


Wells of this kind have been driven at Pondicherry and proved a success. A trial at Madras proved a failure, while at Ennore, near Madras, where the borings have gone much deeper, partial successes have been obtained. Artesian wells are driven to a great depth; one celebrated well, that of Grenelle in France, reached a depth of 1,794 feet. The supply of water from this well exceeded 888,000 gallons per 24 hours. The waters of all artesian wells are not necessarily fit for potable purposes, because the water may hold matters in solution which may render it not only unpalatable but even dangerous to health.

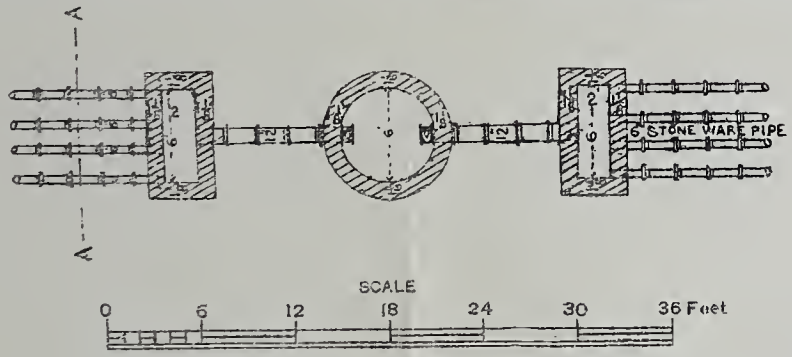
Springs.—Springs are simply places where water naturally issues from the ground where it has been stored in some subterranean stratum; they are, practically, natural artesian wells. The water from these can be collected in cisterns or led on to filter materials and then carried to wells whence it can be distributed by pumping or otherwise. The water-supply of Cuddapah is derived in this way from the Booga springs and the mode of collecting the water is shown on the accompanying plate. The springs formerly fed a channel, this was enlarged, the springs cleared out to some distance back from the channel, both were then filled with clean gravel, collecting pipes having been previously laid at the bottom of the lowered channel; the pipes lead the water to a well whence it is pumped into a service reservoir. At Ootacamund a spring is used to supply what is known as Old Ootacamund; there, loose jointed pipes laid in drains on the hill side carry the water to a cistern whence pipes distribute the supply.

The supply from wells and springs may vary and in dry seasons often fail, so that they are not a sure source of supply until after many years of observation have determined them to be so. In regard to the quantity of water to be obtained from wells and springs no rule can be given; their store is not unlimited, rainfall is their only source of supply; thus the supply cannot be greater than the amount of rain their strata can collect, nor of that portion of it which can be made, or induced, to flow towards them. The estimation of the supply requires considerable experience. Deep seated wells sometimes yield from ·3 to ·5 of the rainfall falling on the surface drained by them. The supply obtainable from a well at any particular period without permanently lowering its surface can be guaged by withdrawing a portion and then observing how long it takes to fill up to the same level, but by permanently lowering the surface, more will

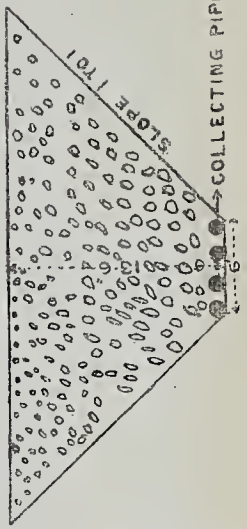
PLAN OF BUGGA SPRINGS (CUDDAPAH)



PLAN SHEWING COLLECTING PIPES AS LAID AT BUGGA SPRINGS



SECTION ON A.A.



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1896

probably be obtainable ; the amount of rainfall, the character of the strata, and its water-bearing capacity, however, limit the quantity finally obtainable without running the well dry.

The greatest percolation takes place in India, during and immediately after the monsoon periods. The greatest quantity of water is collected in broad basins or by the gradual flow through long distances in a porous stratum such as river beds. Fanning makes an approximate calculation of the volume of percolation into one square mile of porous gathering area covered with the ordinary superficial layer of vegetable soil, under unusually favourable conditions, assuming that the mean annual rainfall is 40 inches and that in dry years only 60 per cent. of this annual percolation takes place and gives the following table : —

Percolation of rain into one square mile of porous soil; assumed mean annual rain 40 *Inches depth.*

—	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.
Ratios of $\frac{1}{12}$ of mean annual rain.	·737	·796	1·070	·814	1·462	·964	1·077	1·251	1·015	1·076	·937	·801	
Inches of rain each month.	2·457	2·653	3·567	2·713	4·873	3·213	3·590	4·170	3·383	3·587	3·123	2·670	40
Ratios of percolation.	·50	·40	·45	·15	·055	·02	·01	·005	·01	·20	·50	·70	
Mean inches of rain percolating.	1·228	1·061	1·605	·407	·268	·064	·036	·021	·034	·717	1·561	1·869	
Sixty per cent. of rain percolating in dry years.	·737	·637	·963	·244	·161	·038	·022	·013	·020	·430	·937	1·121	
Volume of percolation in dry years. (cubic feet.)	1,712,198	1,479,878	2,237,242	566,861	374,035	88,282	51,110	30,202	46,464	998,976	2,176,838	2,604,307	
Number of persons it would supply at 5 cubic feet each daily.	11,046	10,570	14,434	3,779	2,413	588	330	195	310	6,445	14,512	16,802	

This table is applicable, of course, only to cases where the monthly distribution of rainfall is similar to that given; the percolation in India during monsoon months does not exceed from 25 per cent. to 30 per cent.; with very heavy rain a very much larger proportion flows off than during more moderate rainfall and during light rainfalls a very large proportion is evaporated.

Fanning says that, from springs with the aid of storage reservoirs, it might be possible to utilize 50 per cent. of the volume of percolation and from wells not more than from 10 per cent. to 20 per cent.

Gathering grounds.—Gathering grounds or catchment basins are in India the most ordinary source of water-supplies. The majority of works already executed are, of course, for irrigation purposes and not for town supplies. Many considerations enter into the question of the selection of gathering grounds for the latter purpose which do not require attention in relation to the former; thus, purity, the results of the chemical analysis of the water obtained from the proposed area, the possibility of protecting the area from future contamination, the absence of inhabited villages or even isolated dwellings, are questions which need hardly be considered in regard to irrigation supplies. The selection of a gathering ground is, therefore, as already stated, a matter which requires considerable study not only with reference to those points noted above, but in regard to the rainfall, its periodicity and variation, the discharge due to the rainfall, &c.

The quantity of water which can be obtained from gathering grounds is difficult to determine. The amount of rainfall itself can be estimated only by a long series of rain-gauge observations and, where the catchment area is extensive and of varied elevation, many rain-gauge stations must have been in existence or must be established and observations at each obtained during many years. The longer the period over which observations have extended the more correctly can the probable annual rainfall be estimated. A good record of thirty-five years may be accepted as sufficient, and a record of fifty years is as good as that of any longer period. If the period of observation is shorter, the probable error may be taken to amount to about the percentages below:—

For a five-years' record	..	16·85	per cent.	error.
,, ten do.	..	9·64	do.	do.
,, fifteen do.	..	6·08	do	do.
,, twenty do.	..	4·77	do.	do.
,, twenty-five do.	..	3·60	do.	do.
,, thirty do.	..	3·03	do.	do.
,, thirty-five do.	..	2·30	do.	do.

That is, the average rainfall may be 16·85 per cent. above or below that determined by a five-years' period of observation, 9·64 per cent. for a ten-years' period, and so on. Average figures are, however, of very little use in dealing with questions of storage, &c., and the plan of obtaining the greatest number of observations available, adding them up and then taking the arithmetical mean is not a method with which engineers will now content themselves. The maximum and minimum falls, the longest consecutive dry and wet periods and the maximum and minimum falls in the three wettest and three driest consecutive years are the points that require the greatest attention. There will, in any record, be years of greatest and least fall, but it is not possible to select such years and determine the size of the gathering ground in relation to the latter and the size of the storage tank in reference to the former; it has been determined that it is practically impossible to spread the equalization over a longer period than three years, and therefore all calculations should be based on the amount of the rain falling in the three driest years that come together.

The following results are taken from tables prepared by Mr. A. Binnie, Inst.C.E., and relate to India; they are based on the records of nine stations extending over a total period of 430 years. Suppose that the arithmetical mean of all the yearly falls is taken as unity, then—

The maximum or wettest years is represented by a fall of	1·62
The minimum or driest years is represented by a fall of	0·52
The two wettest consecutive years is represented by a fall of	1·42
The two driest consecutive years is represented by a fall of	0·66
The three wettest consecutive years is represented by a fall of	1·30
The three driest consecutive years is represented by a fall of	0·72

If these figures are used mathematically and R represents the mean rainfall over a long period (reduced if necessary by the proportion already given),

then the rainfall in wettest year	= 1·62 R
,, rainfall in driest year	= 0·52 R
,, mean of three driest consecutive years	= 0·72 R

While the amount of rainfall is a purely local circumstance, the fluctuations to which it is subject are the same in nature and proportionate amount for nearly all places in the world, the laws governing such fluctuations being apparently of general application.

Approximate determination of yield.—The determination of the probable yield of a gathering ground is somewhat difficult; in estimating the probable yield it is necessary to take into account, the quantity of rain at each fall, the period between each fall, and the geological character of the gathering ground. To estimate accurately the yield, it is necessary, therefore, to know at least the monthly fall during the period of the three driest years. Before going into detailed calculation, however, it is convenient to be able to estimate readily an approximation to the quantity likely to be received. This may be done by considering one-third of the monsoon rainfall in inches (the remaining portion of the fall during the year may be neglected) as possible of collection and storage and taking this the monsoon fall as represented by R^M and A as the area of the gathering ground in acres, then—

$$\text{Cubic feet of water per annum} = 3630\ A\frac{R^M}{3}$$

$$\text{Gallons of water per diem} = 62{\cdot}15\ A\frac{R^M}{3}$$

For example, supposing the monsoon fall of any one year to be 39″ and the drainage area 4,224 acres, the probable collection would be as follows:—

Cubic feet of water per annum $3{,}630 \times 4{,}224 \times \frac{39}{3}$
$= 199{,}330{,}560$

Gallons of water per day $62{\cdot}15 \times 4{,}224 \times \frac{39}{3}$
$= 3{,}412{,}780.$

Estimation of yield.—There is not much to guide an engineer in estimating in detail the probable supply to a tank. Mr. Binnie (now Engineer to the London County Council), when in the Public Works Department of India, made a large number of observations with reference to the

gathering ground of the Ambajheri (Nagpur) tank; these have since been verified by Mr. Penny from the records of 18 years since the construction of the tank. The results of these investigations may be tabulated thus: all other rainfall than monsoon falls should, for the purpose of investigation, be neglected.

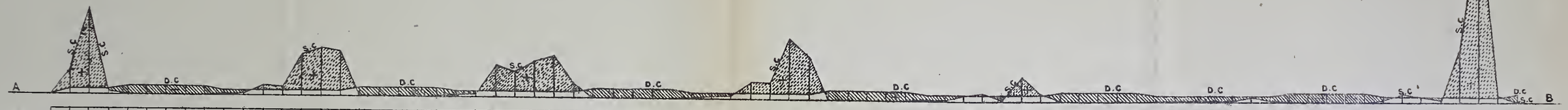
Aggregate monsoon rainfall in inches.	Binnie's percentages.	Aggregate monsoon rainfall in inches.	Binnie's percentages.	Aggregate monsoon rainfall in inches.	Binnie's percentages.	Aggregate monsoon rainfall in inches.	Binnie's percentages.
1	1	13	10	25	22	37	35
2	1	14	11	26	23	38	36
3	2	15	12	27	24	39	37
4	3	16	13	28	25	40	39
5	3	17	14	29	26	41	40
6	4	18	15	30	28	42	40
7	5	19	16	31	29	43	40
8	5	20	17	32	30	44	40
9	6	21	18	33	31	45	40
10	7	22	19	34	32		
11	8	23	20	35	33		
12	9	24	21	36	34		

From these percentages the discharge for each month and the size of the storage reservoir, which is necessary to compensate for the demand during the periods of drought, can be determined.

For example, if the average annual monsoon rainfall in a case where the observations extend for a period of ten years only is as noted below and the drainage area is 18·25 square miles, the supply to the reservoir would be thus estimated :—

Month.	Monsoon rainfall as gauged in inches.	Available rainfall in inches after allowing 9·64 per cent. for probable error or deviation.	Aggregate rainfall in inches up to end of month.	Percentage flowing off ground.	Aggregate flow in inches up to end of month.	Flow during each month.	Yield from total drainage area —million c.ft.
May ...	0·35	0.32	0·32	1	·003	·003	·125
June ...	2·12	1·92	2·24	2	·044	·041	1·720
July ...	1·46	1·32	3·56	3	·1068	·062	2·636
August ...	1·97	1·79	5·35	4	·2140	·107	4·499
September.	5·31	4·80	10·15	8	·8120	·598	25·101
October ..	8·95	8·09	18·24	16	2·9184	2·106	88·399
November .	0·52	0·47	18·71	16	2·9936	0·075	3·156

SUPPLY AND DEMAND CURVES.



| | | |

Capacity of reservoirs.—The method most commonly adopted to decide the capacity, which a storage reservoir should have, depends on the consideration of the greatest period of drought only (in the three driest years). Any probable quantity is then assumed for the capacity and the reservoir supposed to be full at the beginning of period of drought. By simple addition of supply and subtraction of consumption during several months the calculation is continued. Should there be a negative or minus result the capacity is increased and the calculation repeated.

The following formula is an empirical rule based on the conditions which obtain during a period of the three consecutive driest years.

Let R^M be the average *discharge* during the monsoon fall of the three driest years, then the number of days storage to be provided is $\frac{1000}{\sqrt{R^M}} = Z$. For example, taking R^M as 13," then $\sqrt{R^M} = 3{\cdot}6$ and $Z = 277$ days, and the volume of water to be stored is (1) the demand + (2) the loss by evaporation + (3) any other supply such as compensation, water irrigation, &c. The formula is only strictly applicable when (3) amounts to from one-third to one-fourth of the available supply from the drainage or catchment area.

Graphic method of determining the necessary capacity of a tank.—The following is a description of a graphic method for determining the storage capacity of a reservoir proposed by Mr. W. Rippl of Gratz (Styria).

The successive intervals of time, say one month, for which the supply to the reservoir and the outflow from reservoir as estimated are set off along an axis as abscissæ. The available supply to, and the outflow from, the reservoir during each interval are set up as ordinates. The curved lines so obtained are denominated briefly the supply curve and the demand curve.

The demand curve, D C (see plate) would be a uniform straight line, if the draught on the reservoir was exactly the same each month and if the loss due to evaporation were considered as being one-twelfth of the yearly loss. In the diagram, it will be seen that the demand varies, because the loss by evaporation and percolation is based on the area of the water spread of the tank during each month, $\frac{2}{7}$ths of a foot per month being allowed for the monsoon months and $\frac{4}{7}$ths of a foot per month for the other months.

At the end of each month the difference between the two ordinates shows a surplus (positive) or a deficiency (negative) according as the supply is greater or less than the demand. At each interval the ordinates are measured and the surpluses and deficiencies are entered in a table as under :—

Periods for which the successive surpluses and deficiencies are estimated.	Differences.		Algebraic sum or ordinate of mass curve.
	Surplus + When supply ordinate is greater than demand ordinate.	Deficiency — When supply ordinate is less than demand ordinate.	
	Million cubic feet.	Million cubic feet.	Million cubic feet.
1	2	3	4
1877 end of August	...	...	0
1877 end of September ..	20·22	...	20·22
1877 end of October	85·01	...	105·23
1877 end of November ...	..	2·12	103·11
1877 end of December ...	...	8·83	94·28
1878 end of January	...	8·83	85·45
1878 end of February ...	...	8·79	76·66
1878 end of March	...	8·79	67·87
1878 end of April	...	8·79	59·08
1878 end of May	...	4·81	54·27
1878 end of June	...	3·99	50·28
1878 end of July	5·50	...	55·78
1878 end of August	3·94	...	59·72
1878 end of September ...	36·76	...	96·48
1878 end of October	43·46	..	139·94
1878 end of November ...	40·63	..	180·57
1878 end of December ...		8·91	171·66
1879 end of January	...	8·91	162·75
*	*	*	*
*	*	*	*

From the above table the numbers in column 4 are then set off in a diagram as ordinates, the abscissa being the intervals of time as before. The curve obtained by joining the ends of these ordinates is denominated the mass curve and is illustrated in the lower figure of the plate.

When the quantity in the reservoir is increasing, the curve ascends, and when diminishing, the curve descends. The periods, when the supply and the demand are equal, are indicated by crests and hollows H_1, H_2, H_3, H_4, and H_5 in the figure.

The deficiency during the period, from end of October 1877 to end of June 1878, is 105·23—50·28 or 54·95 millions cubic feet. The tank must be of large enough capacity to

cover this deficiency, and the period from which the storage must have commenced to cover this deficiency is found by drawing an horizontal line H_2 K_1, backwards from H_2, until it meets an ascending part of the curve. The lines K_2 H_3 and K_3 H_5 indicate the periods within which the surplus during one part of each period must be stored, to balance the deficiency in another part of the period, with the storage capacities required to meet the fluctuations during each period as shown by vertical lines S_1, S_2 and S_3.

Thus, the greatest possible vertical distance S_3 on the section, which is for a period of over five years and includes the three known driest years, gives the capacity required for the storage reservoir to equalize the period of maximum demand and minimum supply during that period.

The quantity of water which flows away or is not required during the periods represented by K_1 H_2 and K_2 H_3 and K_3 H_5 is shown by the vertical lines W_1, W_2 and W_3.

When the descending part of the curve falls below the line of axis C D, it indicates that the demand during the period considered, is greater than the supply. So long, however, as sum of all the surpluses in column 2 of the table is greater than the sum of the deficiencies in column 3, the supply is enough to meet the demand. The curve will fall below the line of axis for certain reasons, viz., that either the drainage area, the rainfall over which is intercepted by the reservoir, is too small and therefore requires to be extended which is the most probable, or the period of time over which the curve extends is not sufficiently long to give correct results.

Evaporation and absorption.—In India one of the most important points to consider when determining the proper capacity for, or the available supply from, a reservoir or tank, is the loss which must be allowed for, due to evaporation and absorption. The major portion of such loss occurs during the dry season and it is a varying quantity depending on the dryness of the air and the velocity of the wind. The amount to be deducted on this account is, where no observations are available, a matter of experience and an amount varying very greatly at one place from another.

John Dalton's formula for evaporation as simplified by Dr. Pole is —

$$E = \frac{T^2 - t^2}{A\,(100 - W)}$$

T = temperature of the atmosphere in degrees, Farenheit.

t = dew point or the lower temperature at which moisture began to be deposited and which compared with T shows the state of dryness of the atmosphere.

W = velocity of wind in miles per hour.

E = evaporation in inches per diem from a water surface.

A = a co-efficient which is 80 for high temperatures and 100 for low or winter ones.

This formula will be fairly correct for moderate temperatures in India, but for high and dry temperatures the result will be too small.

One point of importance is that a shallow tank will evaporate more than a deep one and for this reason, as well as because less water surface is exposed for the same capacity, tanks should, if possible, be made deep rather than broad.

A fairly safe rule for the plains is to allow for a depth of 6 feet over the average area of the reservoir to cover losses from evaporation and absorption combined and a still closer approximation is obtained by allowing 2 feet of depth for the monsoon months and 4 feet for the non-monsoon months over the mean area. A more correct approximation is to allow the latter depths not over the mean area, but over the area or water spread as under —

For the monsoon months, $L = \frac{2}{7}$ A and for the non-monsoon months, $L = \frac{4}{5}$ A.

Where L = loss by evaporation,

A = water spread or area due to B + $\left(\frac{F-C}{2}\right)$

Where B = balance of water in the reservoir at the end of the previous month in cubic feet.

F = rainfall flow into the reservoir during the month in cubic feet.

C = monthly town consumption in cubic feet.

The following observations were made at the Tansa Lake of the Bombay Water Works during construction, and at seasons when no water was being drawn to the tank and none coming in :—

Date.	1890.		1891.	
	R. L. of lake surface.	Vertical loss in month.	R.L. of lake surface.	Vertical loss in month.
1st January	356·31		380·05	
		0·39		0·44
1st February	355·92		379·61	
		0·63		0·47
1st March	355·29		379·14	
		0·54		0·63
1st April	354·75		378·51	
		0·57		0·64
1st May	354·18		377·87	
		0·81		0·78
1st June	353·37		377·09	
		2·94		2·96

Captain Ward, R.E., (Madras Military Works) prepared a table from which the amount of evaporation, &c., might be estimated. The following figures are extracted therefrom :—

Approximate table of monthly evaporation in feet in a large reservoir due to a given mean temperature and relative humidity.

Mean temperature.	° 65	° 70	° 75	° 80	° 85	° 90	° 93
Degree of humidity saturation = 100.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
88	·14	·17	·19	·21	·24	·27	·30
85	·19	·22	·22	·23	·27	·30	·33
80	·22	·27	·29	·30	·32	·36	·38
75	·24	·29	·33	·35	·37	·40	·42
70	·26	·30	·34	·35	·38	·42	·44
65	·28	·31	·34	·36	·40	·44	·46
60	·30	·35	·38	·40	·42	·47	·49
55	·32	·37	·42	·46	·50	·52	·54
50	·35	·40	·45	·50	·55	·60	·62
45	·45	·50	·57	·67	·71	·75	·78
40	·61	·66	·70	·72	·77	·82	·84

Note.—The above table was compiled from the observations of Mr. Conybeare at the Vehar Reservoir near Bombay, and from those of Mr. Binnie at Nagpur—*See* pages 39 and 60 of "Indian Meteorological" Statistics forming one of the appendices to Jackson's "Hydraulic Manual," Edition of 1875 and table V, page 28 of Mr. A. R. Binnie's paper on the Nagpur Water Works, forming Part I of the Proceedings of the Institution of Civil Engineers during the session of 1874–75. The assumption made in drawing up this table, which can only be considered an approximation to the truth, is that the depth of water evaporated in a large reservoir in any locality varies directly as the mean temperature, and inversely as the mean relative humidity of the air. Where the Bombay and Nagpur data did not agree a mean was taken between them.

Rivers, streams and channels.—Drawing water from these is the fourth method of making rainfall available. In India it is one of very general application, but in the majority of cases for only a portion of the year. Rivers of considerable magnitude only are perennial in India and the chief point to be considered when considering such as a source of supply is in regard to their purity, the results of chemical analysis and whether their waters can be easily rendered fit for potable purposes. All rivers of any magnitude are likely to be turbid, a large amount of impurity being held in mechanical suspension. There will also be mineral impurities derived from subsoil supplies to the river. These would render the water very hard, but this hardness is greatly modified by the amount of surface water which goes to feed the river. The most dangerous impurity in river water is organic contamination due to the population living within its water shed. Organic impurities are not necessarily hurtful; the contamination most to be feared is that of animal origin; but it is not to be supposed that a river is necessarily contaminated with the excreta of the whole population within its water shed. The substances forming animal excreta are very instable in their chemical composition, and their contact or mixture with oxygen tends to turn them into harmless compounds. This takes a certain amount of time, but self-purification of a river is an understood process, and a large river undergoes such a process in a very few miles of its length. Thus the suitability of a river for potable purposes should be gauged not in relation to the population of its catchment area generally, but with regard to pollution from towns on its banks and within a few miles of the site from which water is proposed to be drawn. Calcutta derives its supply from the Hooghli a few miles above Calcutta, and the Hooghli is a river subject to much pollution. Madras derives its supply from the river Cortelliar, but this not being a perennial stream the waters are, during the flood season, diverted from it into a large tank (Red Hills Tank) where it is stored for use during periods of drought.

Subterranean flow under river beds.—The majority of the rivers and streams in India like the Cortelliar are not perennial, but in many cases it is still possible to derive, during the dry season, a considerable supply from the sandy beds of the large rivers. Where rivers drain large areas and have a considerable velocity during flood periods, they, in many cases, have sandy beds; the depth of sand in many river beds, before the hard subsoil is reached, is often

considerable; often also at a lesser depth bands or strata of clay will be found, and below these and above the hard substratum of the bed, a large amount of water is found to pass. This water may be water passing into the river from streams, &c., in the higher reaches of the river which in quantity is insufficient to afford a surface stream, but it is more likely to be derived from the subsoil flow to the river along its whole course. Such subterranean supplies are, therefore, very similar to supplies drawn from wells or excavated tanks with springs, but, of course, the river bottom being the lowest point in its basin, the greatest supply of water is thence necessarily obtainable. The water when proposed to be utilized is either intercepted by galleries placed in the bank of the river or by wells distributed over a portion of the river bed.

Subsoil water.—Water may, of course, be also procured in a similar manner from other sites at which quantities are found to be available such as on slopes below hills, springs in valleys, &c. Subsoil water is found at various depths below the surface, sometimes from 2 to 3 feet, often from 200 to 300 feet. This depends on the quantity of water and the permeability of the soil. Subsoil water is in constant movement along a water course or towards the nearest water course or sea. The rate of flow is very small and has been calculated

at Munich .. .. 15 feet daily

	Mean rate.		Maximum rate.
at Buda Pesth	174 ft.	to	216 ft.;

the level of ground water constantly changes and the variations in India are sometimes large—at Saugor for instance from a few inches to 17 feet, at Jubbulpore from 2 feet to 15 feet, at Calcutta from 5 feet to 15 feet. The height is influenced by the rainfall and the variation of the level of the water in the water course outlet or the level of the sea. Where there are wells or excavations close to the sea, the water will rise and fall almost at the same rate as the tides, as at Madras for instance. To obtain the average height of ground water, numerous observations must be made at many wells scattered over a large area. Subterranean water may be collected by means of galleries or wells, and, as already stated, the best position for these is either in the bed of a stream or river or at the side thereof.

Flood supplies.—When the summer flow of a river in its bed or the supply from under the bed is insufficient, a

portion of the flood discharges of the larger rivers, or the whole, or a portion of the discharge of a smaller stream may be stored in tanks for the supply of a town. The total flood discharge from any river or stream basin may be determined in a manner similar to that already described as a method of determining the yield from gathering grounds. But it is also necessary to determine the maximum flood discharges, so that special works may be designed to secure a sufficient portion of the flood discharges, and to ensure the safety of the reservoir. Such works where they are formed across the bed of a river to divert a portion of the flood discharge, are known as 'anicuts,' and when they are surplus weirs in a tank or reservoir, they are known as 'calingulahs.' In many cases where the flood discharges are considerable, no anicut may be necessary and the water may be passed to a tank or reservoir simply by means of a channel cut directly from the river. The supply to such a channel may be regulated by sluices or otherwise. A calingulah for the tank or a surplus weir on the supply channel is however always necessary for perfect security.

Estimation of flood discharges.—Upon a correct estimate of the amount of the maximum flood discharge depends the safety of works existing, or to be constructed, but an exact determination is not possible (1) because heavy rainfall is partial and a record at one station applies to a very limited area, say, 5 square miles around a station, and (2) because as the size of the basin increases, the flow from the ground near the point of discharge will have cleared before the flow from remoter portions arrives. A fairly accurate estimate is however practicable, if proper use be made of all available data. The chief points to be ascertained are the maximum flood levels and the maximum amount of rainfall. The formulæ in use are the following :—

(1) Ryves' formula, $D = C \sqrt[3]{M^2}$

(2) Dickens' formula, $D = C \sqrt[4]{M^3}$

where M = area of catchment basin in square miles,
D = resulting discharge in cubic feet per second,
C = a co-efficient depending for its value upon the rainfall, soil, slope of ground, &c.

The same co-efficient is not applicable to areas of varied size even in the same part of the country under the influence of the same rainfall, unless the slope of the ground and soil are the same. Values of $\sqrt[3]{M^2}$ and $\sqrt[4]{M^3}$ are given in

the following tables. The chief difficulty is in the selection of a co-efficient. For limited areas near the coast where the country is flat and the drainage takes a longer time to run off, co-efficients of 400 to 500 are applicable to Ryves' formula, and 675 for limited areas near the hills. For Dickens' formula the following have been deduced :—

Maximum rainfall in 24 hours.	Co-efficients.
Inches.	
3·50 4·25	200 flat. 250 mixed. 300 hilly.
5·40 6·20	250 flat. 300 mixed. 350 hilly.
7·60 8·41	300 flat. 350 mixed. 400 hilly.
10·45 13·45	400 flat. 450 mixed. 500 hilly.

The following tables give, for each of the two formulæ with different co-efficients, the depth in inches and discharge in cubic feet per second :—

$D = C M^{\frac{2}{3}}$	Areas in square miles.											
	1		5		10		25		50		100	
Co-efficient.	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
200	7·43	0·20	4·34	0·58	3·35	0·92	2·54	1·71	2·02	2·71	1·60	4·30
300	11·45	0·30	6·52	0·87	5·03	1·39	3·82	2·56	3·03	4·07	2·40	6·46
400	14·87	0·40	8·69	1·16	6·71	1·85	5·09	3·42	4·04	5·42	3·20	8·61
500	18·59	0·50	10·86	1·40	8·39	2·32	6·36	4·27	5·05	6·78	4·00	10·77
600	22·30	0·60	13·03	1·75	10·06	2·78	7·63	5·13	6·06	8·14	4·80	12·92
700	26·02	0·70	15·20	2·04	11·74	3·24	8·90	5·98	7·07	9·50	5·60	15·08
800	29·74	0·80	17·38	2·33	13·42	3·71	10·18	6·84	8·08	10·86	6·40	17·23

Note.—Column *a* = discharge in inches of rainfall from areas in 24 hours.
b = do. in thousands of cubic feet per second.

$D = CM^{\frac{3}{4}}$	Areas in square miles.											
	1		5		10		25		50		100	
Co-efficient.	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*	*a*	*b*
200	7·43	0·20	4·96	0·66	4·18	1·12	3·33	2·23	2·79	3·76	2·35	6·32
300	11·15	0·30	7·44	1·00	6·27	1·68	4·49	3·35	4·19	5·64	3·52	9·48
400	14·87	0·40	9·92	1·33	8·36	2·24	6·66	4·47	5·59	7·52	4·60	12·65
500	18·59	0·50	12·40	1·67	10·45	2·81	8·33	5·59	6·99	9·40	5·78	15·81
600	22·30	0·60	14·88	2·00	12·54	3·37	9·98	6·70	8·38	11·28	7·04	18·97
700	26·02	0·70	17·36	2·33	14·63	3·93	11·65	7·82	9·78	13·16	8·12	22·14
800	29·74	0·80	19·84	2·67	16·72	4·49	13·33	8·94	11·18	15·04	9·20	25·30

Note.—Column *a* = discharge in inches of rainfall from areas in 24 hours.
b = do. in thousands of cubic feet per second.

The method of applying the tables is as follows:—

Suppose the greatest recorded rainfall within or near a basin is 11 inches. The nearest rainfall to this in the table is, in the column for 5 square miles (standard area) 10·86 opposite a co-efficient of 500 for Ryves' formula and between 400 and 500 for Dickens' formula; were there no other data available, either formula with the co-efficient indicated can be used and if the area of basin were 100 square miles, the discharges would be—

By Ryves' formula—10,770 cubic feet per seconds
By Dickens' formula—14,230 cubic feet per second

a very considerable difference.

If, however, there are recorded observations of a portion of an area, which shows that one of the formulæ gives results more applicable to it than the other, then that formula should be adopted to the whole of the basin.

The maximum rainfall to be considered, must be the maximum of 24 hours after a somewhat continuous fall, because, as before explained, the percentage of rainfall received by any storage tank, stream or river increases in a certain proportion with each fall after the ground of the catchment basin has become more soaked or less dry.

The equations for converting discharges in cubic feet a second into inches draining from an area in 24 hours, and *vice versâ*, are—

$$d = \frac{9\,D}{242\,A}$$

$$D = \frac{242\,A.\,d}{9}$$

D = discharge in cubic feet per second,
d = discharge in inches of depth,
A = area in square miles.

Certain formulæ have been prepared which attempt to take into consideration the form of the basin; the chief of these is by Mr. Craig, Mem. Inst. C.E., who divides the basin into triangles, each of which has an angle at the point of discharge and one side on the perimeter of the basin. If 2 B miles represent the length of a side on the perimeter and L miles the distance from its middle point to the point of discharge, the area of the unobstructed flood section in square feet, at the point of discharge A will be—

$$D = 440 \times P \times \Sigma\, B \times \log \frac{8L^2}{B}$$

where D = discharge in cubic feet per second,

P = a co-efficient depending on the rainfall and equal to 0·18 for India,
B and L = as already stated.

Mr. Stent, Public Works Department, in a paper lately issued in the Proceedings of the Institution of Civil Engineers modifies this formula which he arranges thus, (R being the mean annual rainfall)—

1·5 $R \times \Sigma B \log \frac{8 L^2}{B}$ for large areas.

2 $R \times \Sigma B \log \frac{8 L^2}{B}$ for moderate areas.

2·5 $R \times \Sigma B \log \frac{8 L^2}{B}$ for small areas.

River discharges.—Discharges may be determined by these methods—

(1) The maximum discharge by the methods already given.
(2) The ordinary or minimum discharges by—
  i. Measurement of the velocity and the sectional area at the same place.
  ii. Levels showing cross sections and area of the river during the above-noted discharges and the longitudinal sections of the river.

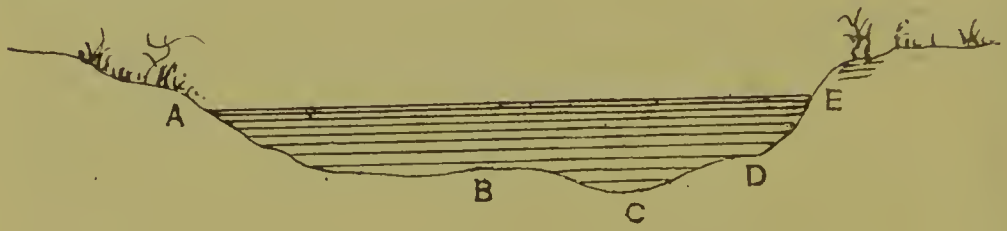
The maximum flood discharge may be checked by observations of the highest flood marks, and either of the methods (No. 2) then applied. When there is always water in the river, wires may be stretched across it along which soundings may be taken with a rod or plummet. If the river is very broad and a wire cannot be stretched, the line of cross sections may be marked with poles on each bank and the position of a boat on the cross sections determined by angular measurements both from the boat and from some point at right angles to the end of the section higher up, or lower down the river. When the river is dry, cross and longitudinal sections can be taken in the usual manner; when a sufficient number of cross sections have been taken and these and the longitudinal sections plotted, the ordinary and minimum depth of water in the bed may be marked on, and the cross sectional area and wetted perimeter calculated and the flow determined on principles to be hereafter enunciated.

Measurement of velocity.—The velocity of a river may be determined by means of hollow velocity rods, reaching to nearly the bottom and immersed at various distances from the banks, which are allowed to float from one cross section to another, the time of passing each cross section being noted.

The cross sections should be divided into segments as nearly equal as possible, and the rod should pass from the centre of one segment on one cross section to the centre of the similar segment on the next cross section. If d = mean depth of the section along which the rod passes, b = the breadth of the segment and v = the velocity per second, then $d \times b \times v$ = quantity per second passed down in that segment and the total of all the segments represents the total discharge. There are other methods of determining the velocity, such as by what are known as current meters, these being furnished with a screw like that of a steamer which revolves at various speeds with the varying velocity of the water, and the velocity is recorded by a counter. This instrument must be used in each segment at several depths between the surface and bottom at each point of observation in order that the mean velocity may be obtained.

Before considering the formulæ applicable to the determination of river and other discharges, it is necessary to explain what is meant by the term "Hydraulic mean depth."

The *hydraulic mean depth* of any stream, river, pipe or conduit is found by dividing the cross sectional area in feet or inches, &c., by the length of the wetted perimeter in similar terms—



Thus if the area ABCDE= 600 square feet and the length ABCDE = 200 lineal feet, then the hydraulic mean depth is $\frac{600}{200} = 3$ feet; again take a pipe running full, the area = $D^2 \times \cdot 7854$ and the perimeter $D \times 3 \cdot 14159$ and the hydraulic mean depth $= \frac{D^2 \times 1}{D \times 4} = \frac{D}{4}$ where D = diameter of the pipe, conduit, &c.; pipes flowing full and half full have the same hydraulic mean depth, but this does not apply to any other depth flowing through circular conduits or pipes.

Measurement of discharges by sections.—It has already been explained how river or channel discharges can

be calculated when the velocity is known, but the determination of the velocity and discharge calculated from the longitudinal sections and the hydraulic mean depth depends on the correct application of a proper co-efficient. The ordinary formula for the velocity of water flowing in a pipe or channel is—

$$v = c\sqrt{rs}$$

where v = velocity in feet per second,
r = the hydraulic mean depth in feet,
s = slope or the rise divided by the length,
c = co-efficient.

The co-efficient c varies, as regards pipes, with reference to the velocity and size of the pipes and also with reference to the roughness of the skin, and in regard to channels, the roughness of the bed and banks, the form of water section and the bed slope.

From the following formulæ the value of c may be determined in relation to river courses, channels, &c.:—

(1) Even surface, fine plaster, planks, &c. .. $c = \dfrac{1}{\sqrt{\cdot0000457\left(\dfrac{r + \cdot098}{r}\right)}}$

(2) Cut stone, brickwork, &c. .. $c = \dfrac{1}{\sqrt{\cdot0000579\left(\dfrac{r + 0\cdot23}{r}\right)}}$

(3) a slightly uneven surface, such as rubble masonry .. .. $c = \dfrac{1}{\sqrt{\cdot00007315\left(\dfrac{r + 0\cdot82}{r}\right)}}$

(4) an uneven surface, such as earth .. $c = \dfrac{1}{\sqrt{\cdot00008534\left(\dfrac{r + 4\cdot1}{r}\right)}}$

Bazin's formula as above has been in use in Madras since 1879, because it is said to have been demonstrated that former tables based on co-efficients adopted by Dubuat, Neville, Downing and other writers are incorrect.

For pipes, however, Neville's formulæ have always been in use in the compiler's department and it is (excepting Weisbach's) the only formula which takes into account the fact that the co-efficient of friction decreases as the velocity

increases. Neville's general formula for rivers, streams and pipes is—

$$v = 140\,(rs)^{\frac{1}{2}} - 11\,(rs)^{\frac{1}{3}}$$

This formula is suitable not only for velocities of 2 to 2½ feet per second, but practically correct for higher and lower velocities.

The following table is calculated from the above formula and if $r\,s$ or v is known, the other can be found by inspection :—

Table for finding the velocity in feet per second from the product of the hydraulic mean depths and hydraulic inclinations, and the reverse calculated from the formula $v = 140\,(rs)^{\frac{1}{2}} - 11\,(rs)^{\frac{1}{3}}$, *in which r, s, and v are feet measures :—*

Values of rs.	Velocity v.	Values of rs.	Velocity v.	Values of rs.	Velocity v.	Values of rs.	Velocity v.
·00000296	·083	·0001302	1·04	·000689	2·70	·003559	6·67
·00000332	·091	·0001322	1·05	·000710	2·75	·003599	6·71
·00000395	·104	·0001420	1·09	·000744	2·83	·003630	6·74
·00000427	·111	·0001482	1·12	·000758	2·85	·003788	6·90
·00000543	·133	·0001532	1·14	·000789	2·91	·003929	7·04
·00000592	·142	·0001578	1·16	·000805	2·94	·003946	7·05
·00000690	·158	·0001610	1·17	·000833	3·00	·003977	7·08
·00000734	·167	·0001657	1·19	·000852	3·04	·004104	7·20
·00000947	·198	·0001736	1·21	·000900	3·13	·004167	7·27
·00000989	·206	·0001776	1·24	·000947	3·22	·004356	7·44
·00001184	·231	·0001815	1·26	·001042	3·40	·004546	7·62
·00001263	·241	·0001894	1·30	·001105	3·51	·004630	7·69
·00001420	·261	·0002052	1·35	·001136	3·57	·004735	7·78
·00001578	·280	·0002131	1·38	·001231	3·73	·005556	8·49
·00001677	·292	·0002265	1·43	·001246	3·76	·006944	9·61
·00001894	·316	·0002367	1·47	·001263	3·78	·007576	10·0
·00001973	·325	·0002552	1·50	·001302	3·85	·008333	10·5
·00002170	·345	·0002604	1·55	·001326	3·89	·009259	11·1
·00002367	·365	·0002652	1·57	·001420	4·04	·010417	11·8
·00002565	·385	·0002778	1·61	·001515	4·18	·011905	12·7
·00002841	·411	·0002841	1·63	·001576	4·28	·013889	13·8
·00003255	·448	·0003030	1·69	·001610	4·32	·015151	14·5
·00003354	·457	·0003157	1·73	·001667	4·41	·016667	15·3
·00003551	·473	·0003220	1·75	·001705	4·46	·017297	15·6
·00003748	·489	·0003314	1·79	·001735	4·51	·020833	17·1
·00003946	·505	·0003378	1·80	·001799	4·60	·027778	20·2
·00004143	·521	·0003409	1·81	·001894	4·73	·029167	20·6
·00004340	·536	·0003551	1·85	·001989	4·87	·041666	24·7
·00004632	·558	·0003630	1·89	·002052	4·94	·055556	28·8
·00005130	·594	·0003706	1·90	·002083	4·98	·062500	30·6
·00005327	·608	·0003788	1·92	·002093	5·00	·072916	33·2
·00005524	·622	·0003946	1·98	·002178	5·10	·083333	35·6
·00005919	·648	·0004022	1·10	·002210	5·14	·104167	40·0
·00006314	·674	·0004103	2·02	·002273	5·22	·125	43·9
·00006708	·699	·0004261	2·06	·002375	5·35	·145583	47·6
·0000688	·711	·0004419	2·10	·002462	5·46	·166667	51·1
·00007102	·724	·0004485	2·12	·002533	5·53	·208333	57·3
·00007694	·760	·0004546	2·14	·002652	5·68	·229167	60·2
·00008049	·781	·0004708	2·18	·002683	5·72	·250000	63·0
·00008523	·808	·0004735	2·18	·002841	5·90	·270833	65·7
·00008681	·828	·0004893	2·23	·002968	6·05	.312500	70·7
·00009270	·849	·0005051	2·27	·002999	6·08	·333333	73·2
·00009470	·861	·0005208	2·31	·003030	6·11	·354167	75·5
·00010259	·903	·0005303	2·33	·003143	6·23	·375000	77·7
·00010654	·923	·0005638	2·41	·003157	6·25	·395833	80·0
·00011048	·945	·0006061	2·52	·003214	6·31	·416667	82·1
·00011361	·960	·0006155	2·54	·003220	6·32	·437500	84·2
·00011837	·983	·0006313	2·57	·003314	6·42	·458333	86·2
·00012232	1·00	·0006440	2·60	·003409	6·51	·479166	88·3
·00012627	1·02	·0006629	2·64	·003475	6·58	·500000	90·2

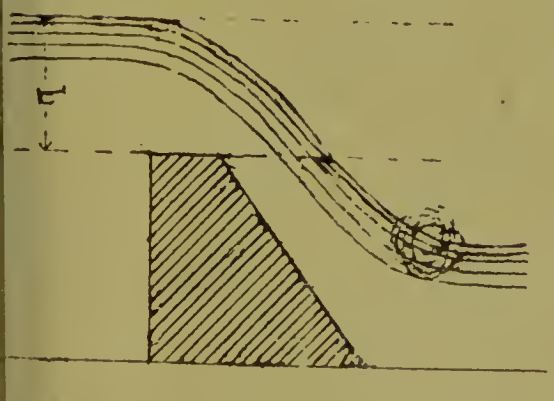
thus, if $rs = \cdot03125$, then we shall have—

$v = 20\cdot6$	when	rs =	$\cdot029167$
$v = 24\cdot7$	when	rs =	$\cdot041666$
Difference $4\cdot1$	corresponds to		$\cdot012499$
			$\cdot03125$
			$\cdot02917$
Difference			$\cdot00208$

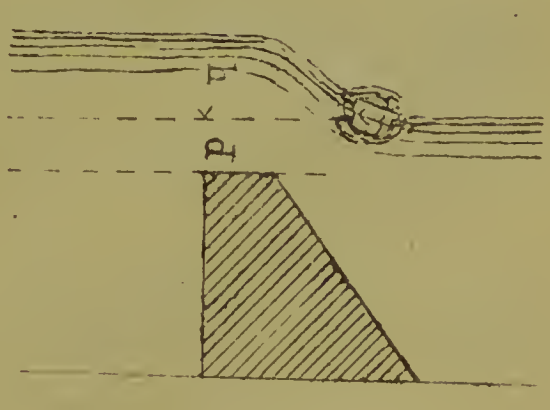
Whence $\cdot0125 : 4\cdot1 :: \cdot00208 : \cdot7$ nearly, and $20\cdot6 + \cdot7 = 21\cdot3$ which is the velocity sought.

Anicuts or weirs.—When supplies have to be taken from rivers, anicuts are generally necessary to raise the level of the water, so as to discharge a portion of it down a channel of reasonable depth, and to allow of its flowing by gravitation through the country on the banks of the river either for irrigation or for storage purposes. In this work the latter purpose only, need be referred to; when drawing up projects for water-supply from rivers, the minimum, ordinary, and flood discharges must be considered so that the dimensions of the anicut sluices, height of flood banks, &c., may be fixed. To determine the height to which an anicut and also the banks above and below it must be raised, are questions that require considerable attention, but it is not practical to enter into such questions in detail in this work, and the formulæ by which results may be arrived at alone are given. Anicuts or weirs may be classed as (1) free or overfall weirs, (2) submerged or drowned weirs. To these two classes the following formulæ are respectively applied :—

Free overfall weir



Drowned weir



Discharges over free overfall weirs.—To the free overfall weir two formulæ apply; (1) when the discharge is from a large still water basin, (2) when the water approaches it with a sensible velocity. The formulæ are as follow:—

Let Q = discharge per second,
c = a co-efficient,
l = length of anicut or weir,
h = the height,

then $Q = \frac{2}{3} c\, l\, h \sqrt{2gh}$ (1)

If the water approaches with a velocity, then an addition to the height h say h_a must be made and this may be calculated thus—

$$h_a = \frac{V^2}{2g}$$

where V = the velocity of approach in feet per second.

The formula then becomes—

$$Q = \frac{2}{3} c\, l \sqrt{2g} \left\{ (h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\} \quad (2)$$

The two preceding formulæ, if used with a co-efficient of 0·577, can be stated thus—

$$Q = 3{\cdot}1\, l \sqrt{h^3}$$

$$Q = 3{\cdot}1\, l \left\{ (h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$ if the stream is in motion.

Discharges over drowned weirs.—For submerged anicuts or drowned weirs, the formula for the discharge may be first taken in two parts—

Let d = the height of the back water above top of weir,
h = the remaining height to surface of water above weir,

then the discharges from the two portions are—

$$Q = \frac{2}{3} c_1\, l \sqrt{2g} \left\{ (h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\}$$

$$Q_1 = c_2\, l\, d \sqrt{2g\,(h + h_a)}$$

The value of the co-efficient c_1 is usually taken as 0·577 and $c_2 = {\cdot}8$. If these co-efficients are adopted, the formula for the total discharge may be written thus—

$$Q = l \left[3{\cdot}1 \left\{ (h + h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}} \right\} + 6{\cdot}4\, d\, (h + h_a)^{\frac{1}{2}} \right]$$

From this equation can be obtained the height h due to a maximum flood discharge; the value of h so deduced is added to the maximum depth at which the river flows and thus the height of wing walls, head sluices and flood banks can be fixed.

The following examples are from Major Love's Hydraulics :—

(1) The maximum flood discharge of a river is estimated at 5,000,000 cubic yards per hour, the mean velocity being 500 feet per minute. An anicut is to be built across the river, 450 feet long, with its crest $4\frac{1}{2}$ feet above bed. What must be the height of the wing walls and head sluice, so that a maximum flood may not rise within three feet of their tops ?

$$Q = l\left[3{\cdot}1\left\{(h+h_a)^{\frac{3}{2}} - h_a^{\frac{3}{2}}\right\} + 6{\cdot}4d\left(h+h_a\right)^{\frac{1}{2}}\right]$$

Here $Q = \dfrac{5000000 \times 27}{60 \times 60} = 37500$ c.ft. per sec. ; $v = \dfrac{500}{60}$

$$A = \frac{Q}{v} = 4500 \text{ s. ft.} \quad \text{Mean depth} = \frac{A}{l} = 10 \text{ ft.}$$

$d = 10 - 4{\cdot}5 = 5{\cdot}5$ feet. Taking the velocity of approach equal to the mean velocity,

$$h_a = \frac{(8{\cdot}33)^2}{64} = 1{\cdot}08 ; \quad \therefore \left(h_a\right)^{\frac{3}{2}} = 1{\cdot}12$$

Let $\sqrt{h + 1{\cdot}08} = x$; $37500 = 450\,[3{\cdot}1\,(x^3 - 1{\cdot}12) + 6{\cdot}4 \times 5{\cdot}5x]$

$\therefore x^3 + 11{\cdot}3x = 28$. Try $x = 2$; $8 + 22{\cdot}6 = 30{\cdot}6$

Try $x = 1{\cdot}9$; $6{\cdot}86 + 21{\cdot}47 = 28{\cdot}3$

$\therefore x = 1{\cdot}9$; $\therefore h + 1{\cdot}08 = (1{\cdot}9)^2 = 3{\cdot}61$; $\therefore h = 2{\cdot}53$

$\therefore$ Top of wing walls must be $3 + 2{\cdot}53$ or $5{\cdot}53$ feet above anicut crest.

(2) An anicut 1,500 feet long is to be built across a river. The full supply depth in the channel, above the floor of the head sluice, is 7·0 feet, and the area of the sluice openings is such that a head of 6 inches is requisite to furnish the given supply. The normal water section of the river is 7,500 square feet, and the estimated normal discharge 30,000 cubic feet per second. What should be the height of the crest of the anicut above level of sluice floor, the latter being placed at the bed of the river ?

$$\text{Mean depth of river} = \frac{A}{l} = \frac{7500}{1500} = 5 \text{ feet.}$$

The water surface has to be raised through $(7{\cdot}0 - 5{\cdot}0) + 0{\cdot}5$, or 2·5 ft.

$$Q = l\left[3{\cdot}1\left\{\left(h+h_a\right)^{\frac{3}{2}} - h_a^{\frac{3}{2}}\right\} + 6{\cdot}4\,d\left(h+h_a\right)^{\frac{1}{2}}\right]$$

Here $Q = 30000$; $l = 1500$; $h = 2{\cdot}5$ feet. Taking the velocity of approach equal to the mean velocity, *i.e.*, equal to $\frac{Q}{A} = 4$, we have $h_a = \frac{(4)^2}{64} = {\cdot}25$

$$30000 = 1500\left[3{\cdot}1\left\{(2{\cdot}75)^{\frac{3}{2}} - ({\cdot}25)^{\frac{3}{2}}\right\} + 6{\cdot}4d\ (2{\cdot}75)^{\frac{1}{2}}\right]$$

$$\therefore\ 20 = 3{\cdot}1\ (4{\cdot}56 - {\cdot}13) + 6{\cdot}4d \times 1{\cdot}66\ ;\ \therefore\ d = {\cdot}6$$

Hence height of crest above sluice floor is $5{\cdot}0 - 0{\cdot}6 = 4{\cdot}4$ ft.

If d had come out negative, it would indicate that the anicut crest must be above tail water. Equation (2) for a clear overfall should in this case be solved for h. Then $7{\cdot}5 - h$ will give height of anicut above sluice floor.

The following tables will be found useful:—

Free Overfall Weirs.

Table of Discharge from each Foot of width of sill in cubic feet per Minute.

Depth of sill.	Decimals of an inch.									
	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
INCH.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.
...	...	·162	·46	·846	1·30	1·823	2·34	3·02	3·68	4·4
1	5·15	5·92	6·75	7·62	8·55	9·42	10·4	11·38	12·41	13·49
2	14·57	15·65	16·79	17·97	19·16	20·34	21·58	22·87	24·1	25·44
3	26·78	28·12	29·56	30·9	32·14	33·78	35·28	36·77	38·16	39·55
4	41·2	42·74	44·29	45·78	47·48	49·13	50·73	52·53	54·07	55·62
5	57·58	59·17	60·92	62·83	64·53	66·33	68·29	70·04	71·89	73·9
6	75·70	77·56	79·46	81·42	83·38	85·23	87·24	89·35	91·26	93·26
7	95·38	97·44	99·54	101·6	103·6	105·8	107·9	109·9	112·1	114·3
8	116·5	118·6	120·9	123·1	125·4	127·6	129·8	133·0	134·4	136·7
9	139	141·3	143·9	146	148·4	150·7	153·2	155·5	157·9	160·4
10	162·8	165·3	167·7	170·2	172·7	175·2	177·7	180·2	182·8	185·3
11	187·9	190·4	193	195·6	198·2	200·8	203·4	206·1	208·7	211·4
12	214·1	216·7	219·4	222·1	224·8	227·5	230·3	233	235·8	238·5

Depth of sill.	Decimals of a foot.									
	·0	·1	·2	·3	·4	·5	·6	·7	·8	·9
FOOT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.	C. FT.
...	...	6·7	19	34	53	75	99	125	153	183
1	214	246	280	317	357	391	432	472	515	560
2	605	650	697	746	796	845	896	950	1,001	1,057
3	1,112	1,168	1,228	1,284	1,335	1,401	1,465	1,527	1,585	1,643
4	1,712	1,776	1,840	1,902	1,973	2,041	2,107	2,182	2,247	2,311
5	2,392	2,458	2,531	2,610	2,681	2,756	2,838	2,910	2,987	3,070
6	3,145	3,222	3,302	3,883	3,464	3,541	3,625	3,712	3,792	3,875
7	3,963	4,049	4,132	4,220	4,305	4,395	4,483	4,569	4,658	4,751
8	4,843	4,930	5,022	5,116	5,210	5,303	5,397	5,489	5,583	5,682
9	5,778	5,872	5,970	6,067	6,165	6,264	6,364	6,463	6,563	6,664

Referring to the formula for the discharge over weirs or calingulahs, applying a co-efficient of 0·67, the formula becomes—

$$Q = 3{\cdot}56\, l\, h^{\frac{3}{2}}$$

if the maximum discharge is known and the height h of the flow over the calingulah is fixed, then

$$l = \frac{2}{7}\,\frac{Q}{h\sqrt{h}} \text{ (nearly).}$$

The level of a calingulah of a tank is known as full tank level and if to this be added, the maximum depth intended to flow over the calingulah, the upper level is known as the maximum tank level; the banks of a tank above this latter level should be from 3 to 6 feet.

Sluice discharges.—The discharge from sluices, square or circular, or of a form of which is symmetrical above and below an horizontal axis, may be found from the formula—

$$Q = c\,\mathrm{A}\,\sqrt{2\,g\,h}$$

where h = difference of the height of the water on either side of the sluice: the value of the co-efficient c may be taken as 0·62 for ordinary tank sluices.

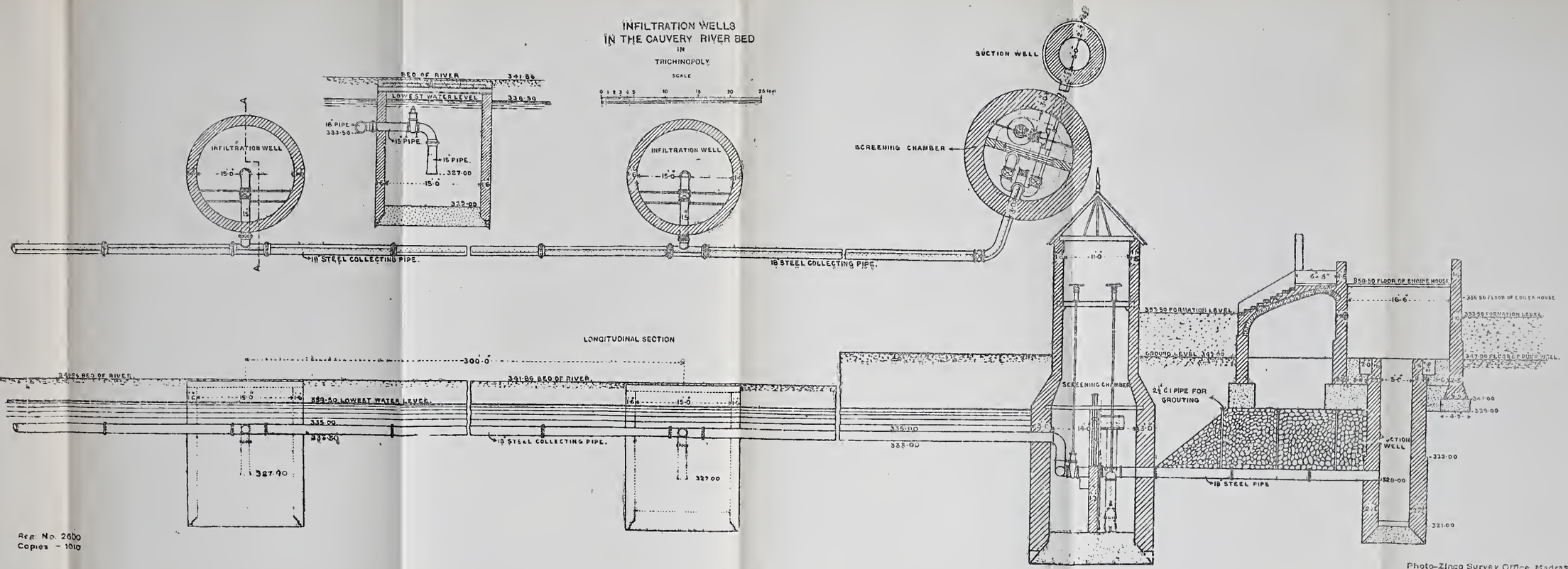
Infiltration wells and galleries.—The method of obtaining water by means of wells or galleries sunk in porous soils is a common one in India, and is a method frequently used in the Punjaub, where many towns procure their water-supply by this system. Shallow wells, as has been pointed out, are not, as a rule, a preferable source of water-supply, but the water obtained by sinking a well into a stratum of sand or gravel, which has not been distributed and which is in or adjacent to a river bed or in a valley having a large area of a porous character, is, as a rule, bright and clear and nearly free from organic matters. The slow passage of such water through such soils has subjected it to sedimentation and filtration combined with oxidation; in fact the water has undergone what is known as the process of natural filtration.

The most simple method of obtaining water in this way, and it is one practised in many parts of Southern India, is to dig a basin or tank into which the water flows and then to lead off from this a channel which conducts the water to the place where it is required; the town of Conjeeveram is at present supplied in this way; one objection to the method

is that there must be a rapid fall away from, or along, the river to allow the channel to be taken off at such a level as will not necessitate very extensive cutting; if the channel is not placed sufficiently low, it will receive water for only a portion of the year. This objection to the system disappears if the water can be conveniently stored.

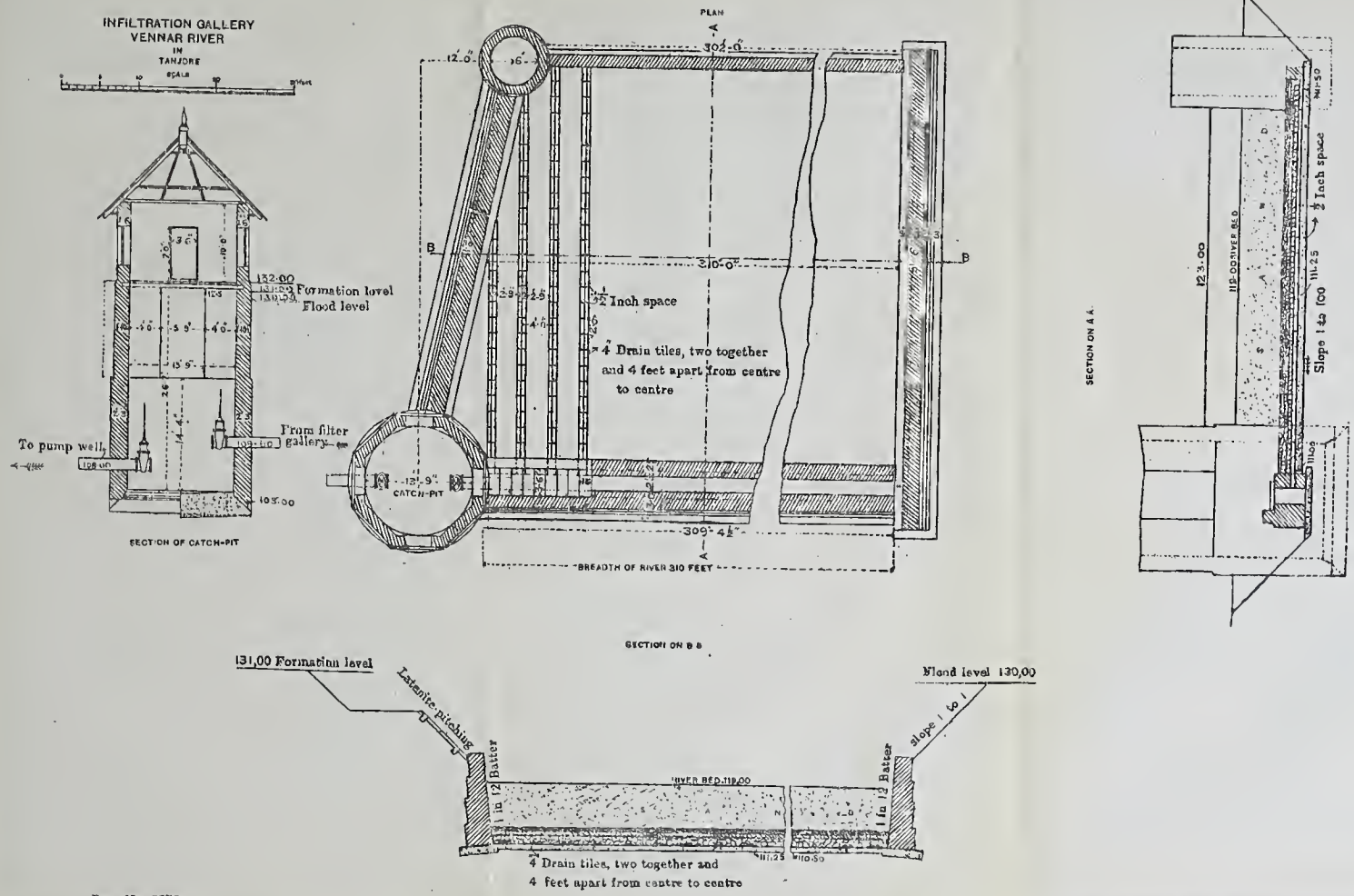
Filtration wells.—In more modern works, however, and in some ancient ones, the plan adopted is to sink either a well, or wells or a gallery and pump therefrom. The wells may be ordinary brick wells, open or closed, and may draw the supply entirely from the bottom, or from the bottom and the sides as high as the water level extends. A gallery may be in the form of a conduit, a barrel drain or a perforated pipe, or of pipes laid with loose joints; such pipes are usually laid in gravel of a size larger than will pass through the perforations or joints into the pipes. Where these wells, galleries or conduits are adjacent to a river, they may draw not only from the river itself, but from ground water approaching the river. Many conduits are built water-tight on that side next the river bank, so that all water whether drawn from the river or not, shall enter that side of the conduit furthest away from the river, and thus better filtration for the river water is secured. It is often observed that springs issue from alluvial areas adjacent to the sea, the waters from which are perfectly fresh. This is the case at Madras, Tuticorin, &c.; after being drawn on for some time such springs of water may lose their fresh character. In such wells the water rises and falls with the tide as the water must enter the sea under the pressure of a varying height of salt water, but the salt water will not penetrate the soil and reach the well itself because the pressure of the subsoil water from land, its surface gradually rising as it recedes from the sea, is greater than that due to the sea; if, however, pumping takes place and the amount exceeds the quantity the ground can furnish, salt water enters the well. At Tuticorin this very frequently takes place and a well seldom furnishes fresh water for more than a few months. In Holland, Amsterdam and the Hague obtain their water from collecting pipes laid in the sand dunes which form a barren strip of country one mile to two and a half miles wide. In India the beds of the larger rivers form an excellent strata from which supplies of fresh water may be derived by means of galleries or wells. In Southern India the towns of Trichinopoly, Tanjore, and Madura are so supplied, while the town of Cuddapah already referred to derives its supply from a gallery fed by springs adjacent to a small stream (*vide* plate

INFILTRATION WELLS IN THE CAUVERY RIVER BED IN TRICHINOPOLY



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1886



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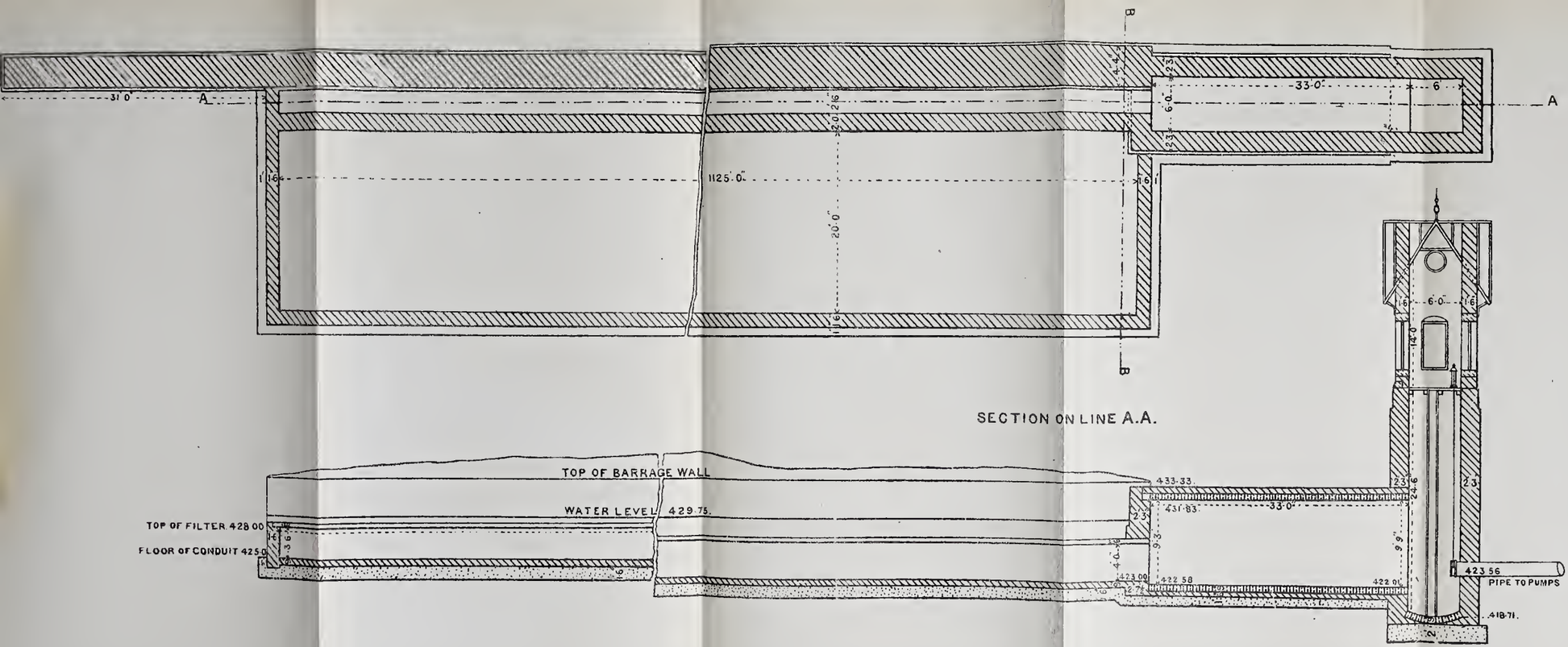
INFILTRATION GALLERY IN VAIGAI RIVER

IN

MADURA

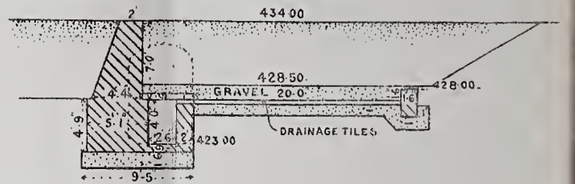
SCALE

0 5 10 20 30 Feet

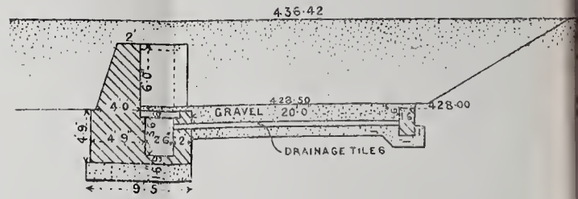


SECTION ON LINE A.A.

SECTION ON LINE B.B.



SECTION AT CENTRE.



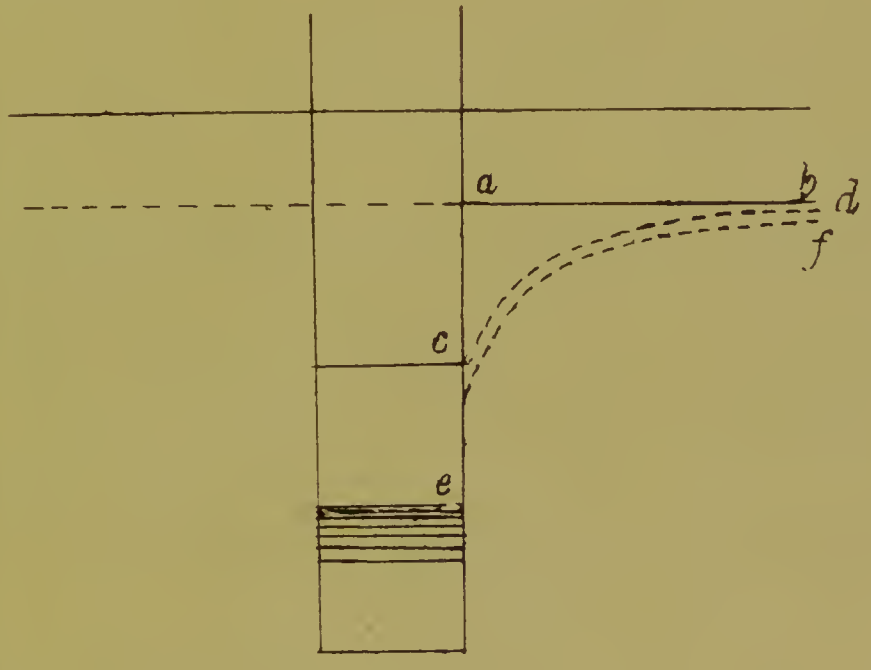
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1895

facing page 250), but not depending upon a supply from the latter. The methods employed at each of these several places are illustrated.

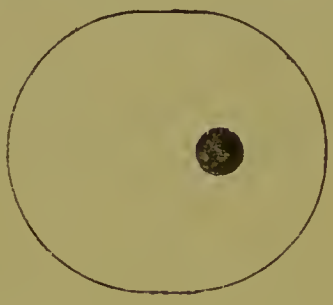
Ground water-supplies.—A knowledge of the laws governing the supply of ground water to wells, galleries, &c., is at present very limited, but the yield in all cases depends primarily upon the nature of the surrounding soil. If the material is fine close sand with an admixture of clay, the flow is much slower than it would be through sand of clean coarse grain and as the surface slope of the water approaching the well must vary with the velocity, this slope is an important factor in considering the yield.

Suppose a well is sunk in a homogeneous soil and that the line *a b* represents the original level of sub-soil water; when



pumping takes place, the water falls at first rapidly, afterwards more slowly, until, if the discharge of the pump be uniform, a level is reached where the water is supplied exactly at the same rate as that at which it is being withdrawn. Let the line marked *c* be at this level. The water flows into the well by virtue of the head *a c*, but its flow is retarded by the friction of the particles of the soil through which the water is flowing and the surface of the water takes a form similar to what is shown in the diagram. The line *c d* approaches the line *a b* until it finally meets it at a point beyond which the influence of the pumping is not measurable. The slope and therefore the distance of the point of intersection varies, as

already stated, with the nature of the strata around the wells*. A line drawn through all the points of intersection around a well will not form a circle, because all subsoil water has a natural direction of flow and the points of intersection above the well opposite to the direction of flow would be at a greater distance than similar points of intersection on a line passing through the well down stream. Similarly on either side of a well the points of intersection would be at a less distance than the former but at a greater than the latter; the so-called drainage cone would, therefore, be in plan of this form.



Experiments in regard to the flow of water to wells have been made in several places; for instance by Piefker at Berlin, who found that, when a well was pumped down to a distance of 2·23 meters below the normal level of the ground water, the lowering at 50 meters was 0·35 meter, at 100 meters 0·17, and at 260 meters 0·10 meter. The natural movement of this ground water is very slow. In connection with experiments made at Dresden on the banks of the Elbe, a well, kept 2·5 meters below normal water level, affected the water around to a distance of 60 meters (200 feet).

If, by increasing the quantity pumped, the well is lowered below a point where the demand and supply are equal, a further lowering of the level of the subsoil water will take place and the curve assumed will be somewhat that shown as *e f*: the largest quantity which can be obtained from a well will be when the quantity pumped is equal to the inflow and when a constant level of water just above the pump foot valve is maintained; but in practice this maximum cannot be depended on, because any head on the well more than 5 feet to 6 feet is likely to drive the sand in from the outside and fill up the well. It should be remembered that the head is the difference between the level of the water inside the well and the level

* When the subsoil water is in motion, this slope is flattened above a well and increased below it.

(*not* just outside but) at the point where the curve tangents the water slope. The reduction of level of water surface outside a well is, when pumping begins, very much slower than that inside, and only when nearing the point of exhaustion of supply will the outer level begin to approach the inner water level with some rapidity. The reduction of water level on the outside and close to a well is due to the extension of the drainage cone, because the difference between this and the original or normal level is the head lost in driving the water through a certain length of sand, and as this length increases, the loss of head increases; the fall of level inside the well is due to the off-take through the pumps being in excess of the supply from the drainage cone or the less permeability of the walls of the wells than the rate of flow outside.

Wells and galleries are, of course, sunk in some strata which are continually receiving accessions from rain or a neighbouring stream, but the amount which can be obtained is never inexhaustible, and depends on the amount received by the strata and wells must therefore never be called upon to furnish more than they can supply. Constant draught in many strata will permanently lower the level of the ground water, and a well in Brooklyn, N.Y., shewed the following decreases :—

Year.	Draught.	Feet above tide level.
1869	.....	14·55
1870	300,000 gallons per day ...	14·15
1871	272,000 gallons per day ...	13·03
1872	437,000 gallons per day ...	10·56
1873	288,000 gallons per day ...	11·29
1874	333,000 gallons per day ...	10·70
1875	294,000 gallons per day ...	9·83
1876	235,000 gallons per day ...	9·83
1877	252,000 gallons per day ...	9·21

It will be seen that an average draught of 301,000 gallons lowered the level of the water table 5 feet in eight years and also that the yield is diminishing.

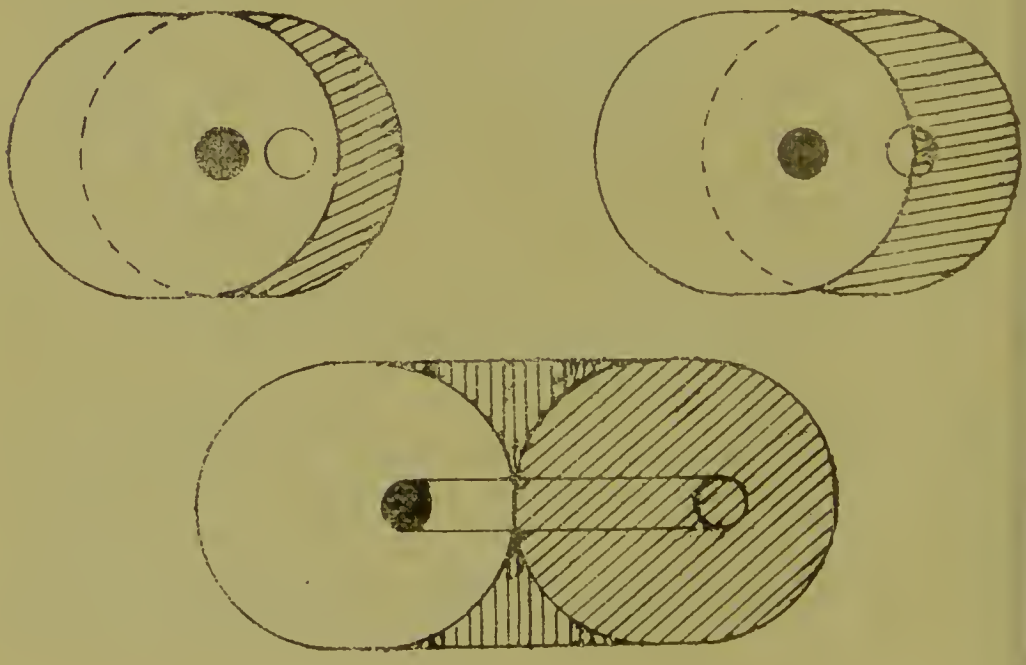
On page 280 the diagram shows the area influenced by one well; the effect of increasing the size of a well or placing two wells, or a series of wells close together or of forming a gallery is to increase that area, the increase of the length and breadth of the area being equal to the difference between the lengths of diameters of the larger well and the original

well or by the combined diameters of the additional wells or additional length of gallery, thus—



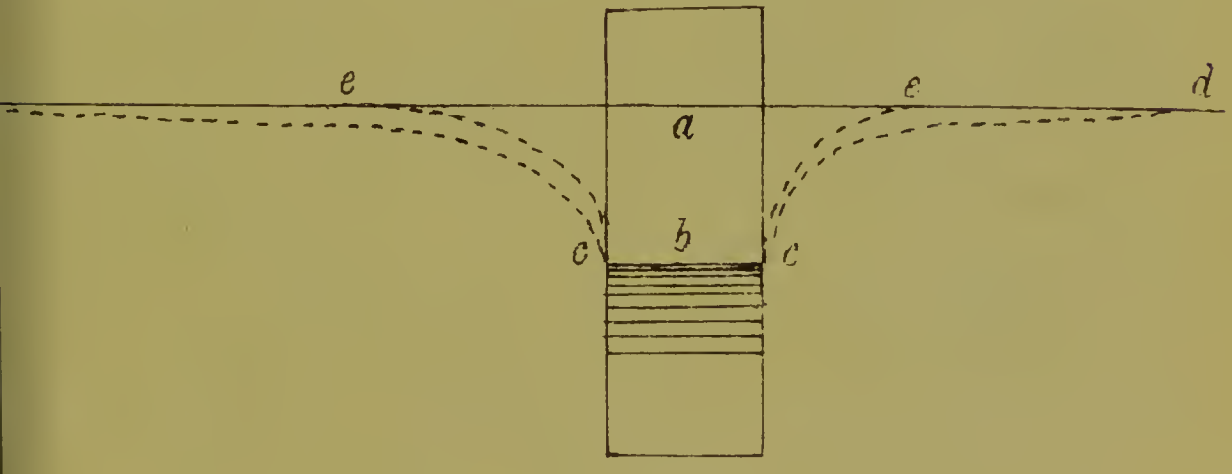
If wells are placed on either side of the original well, or if a gallery of the length *a b* be formed in place of the original well, the increase of area would be that shown between the full and dotted lines.

In many schemes for water-supply by the method of wells, it has been a source of error to suppose that an increase in the well area, gave a proportionate increased supply. This, as will be seen, is not the case; in fact the increase is very limited and either a very long gallery must be used to obtain such increase or additional wells must be sunk outside the drainage cone of the original well; to place a well inside such area would obtain a somewhat larger supply, but only when wells are so far apart that their drainage cones do not overlap, will the greatest possible supply from each well be obtained: thus, the shaded area shews the increase in each case, the extra area available for supply, in case of a gallery being constructed, would be the portion shaded vertically.



Tho estimation of the supply, which a well will yield for years without reduction in quantity or the level of the water table, is a difficult question, and this can be done only by many experiments and by a determination of a sufficiently large number of co-efficients applicable to the different strata from which water may be drawn.

In determining the possible supply the main question is the gradient assumed by the water table when pumping takes place. A reduction of the head in the well does not alter this gradient except within 50 to 100 feet from the well, the tangent point of the curve getting further and further away, but it increases the area of the so-called drainage cone; the slopes however in the fine, coarse, or close, and porous soils are materially different and the longer the slope the greater the yield, thus :—



If the water level in the well be reduced from *a* to *b*, then if the soil were very porous the water table slope might assume a position such as *c d*, and in a soil of close texture the line would be somewhat like *c e*.

In designing water works where the above system of obtaining tho supply is to be adopted, the first matter to be decided is the head by which water in a well can be safely lowered, that is without bringing in the sand (though this can be somewhat increased by filling the well for some height with gravel and stones), secondly, by experiment to fix the dimonsions of the drainage cone, and, thirdly, the dischargo which can be got from a single experimental well; this well should be as near the size likely to be adopted as

possible, but as already shown the yield will not be very greatly increased by an increase in size.

Various attempts have been made to determine co-efficients in relation to the flow through coarse and fine sand, &c., but these and other accompanying formulæ are of no real value and would by their use be more likely to lead astray than to guide to any correct decision as to the number and size of wells or galleries required in any particular situation.

The following particulars of works actually executed may however be of use :—

Wells and open Trenches.

Place.	Inner and outer diameter of well in feet.	Head below normal W.L.	Yield in gallons per hour.	Mean length of slope of water surface.	Remarks.
	I. O.				
Lahore ...	11 —14	3	8,850	130	Experimental well.
Amritsar...	20 —24	5	2,450	37	
	$11\frac{1}{4}$—15	9	4,648	37	
Umballa ...	6 — 0	8	1,668	26·8	
Trichinopoly	4 — 6	$1\frac{1}{2}$	4,200	about 300	
Ahmedabad	25 —$29\frac{1}{2}$	5	20,000 to 25,000	...	There are four wells 250 feet apart.
	Open trench. L. W.				
Amritsar ...	200 × 5	$8\frac{1}{2}$	15,300	...	Experimental trench.
Cuddapah ...	* Open jointed pipes in trenches.	...	174,000	...	This is the daily demand.

* See page 250 for plan.

Covered Galleries.

Place.	River, &c.	Dimensions, Feet.	Number of gallons per 24 hours.	Number of gallons per square foot of area.	Remarks.
		L. W. H.			
Lowell (Mass) ...	Merrimac ...	1,300 × 8 × 8	1,500,000	150	Gallery 100 feet from river.
Brookline (Mass).	Charles River	762 × 4 × 3	1,500,000	490 160	Maximum. Ordinary.
		Open basin.			
Toronto	Lake Ontario	3,090 × 26½	708,333	52	Bottom of gallery 6½ feet below lowest water average head 5 feet.
Perth	Tay	300 × 4 × 8	200,000	182	Bottom of gallery 2¼ feet below low water.
Angers	Loire ...	* 288 × — × —	.....	187	7½ to 9½ feet below low water.
Lyons	Rhone ...	394 × 16½ × — 328 × 33 × — 2 Basins rectangular	4,250,000	100	Total bottom area 57,706 square feet.
Toulouse ...	Garonne ...	1,180 × 7½ × 8⅔	2,500,000	228	Floor 8 feet 7 inches below low water surface.
Genoa	Scrivia ...	1,780 × 5 × 8	11,500,000	1,300	Gallery partly under bed of stream.
Madura	Vigai ...	1,125 × 20	600,000	27	Filter beds across river. The figures shew the present demand, the yield varies but is likely to exceed 15 gallons per head for 100,000 people and 60,000 respectively.
Tanjore	Vennar ...	310 × 51½	300,000	19	
		Miles.			
Karachi	Malir ...	(1) 6 × 6′ × 2·0 (2) — × 2 × 1·6	2,500,000	.....	There are several galleries in connection with the banks of the river wells 40 feet diameter, 39 feet deep and 30 feet below bed of river. Long gallery connects wells along the river.

* Part of gallery 3′4″ wide, part 6′0″.

In many of these cases, perhaps most, galleries intercept the flow of underground water to the river; a rise in the river level naturally increases the supply because that rise raises the level of the underground water, and the head on the supply to the galleries. That the water does not always come from the river is shown by chemical examination. The river, in some cases, is a source of supply in dry weather, in wet weather the supply is ground water. At Perth the gallery is located on an island in the river and in this place it is neeessarily a case of filtration of river water.

THE CONSTRUCTION OF TANKS.

The best position for a tank bund is in a valley with moderate longitudinal and transverse slopes at a point where the bund will be of moderate length with suitable abutments at either ends, where the bund will be moderate in height with a moderate depth of water, where suitable material is to be obtained for the construction of the bund, and where there are facilities such as as hard ground or rocky spurs at either, or one end, to enable surplus water to be conveniently diseharged.

The design for a reservoir will include (1) the bund, (2) the outlet sluice or culvert and pipes and (3) a surplus weir. After the maximum and full tank levels have been fixed, the bund and other works may be designed. The bund, in India, consists usually of earth with a centre puddle wall. The top width of a bund ought not to be less than 8 feet nor less than one-fourth of the depth of water against it, within a maximum of 18 feet. The width may be reduced at the ends where the depth of water is less. The height of the bund above maximum water level should not be less than 4 feet, nor less than one-eighth of the depth of water against it.

Earth work.—The earth for the bund should be taken from the land inside the proposed tank; the earth should be punned in layers not more than 6 inches thick. All vegetable soil ought to be cleared from beneath the core of the embankment and the subsoil, rolled and compacted with a heavy roller.

Revetments.—The inside face of the bund should be revetted and the slopes for large regular stones may be 1 to 1 and for shingle $1\frac{1}{2}$ to 1; the upper portion of the slope should approach more nearly to the vertical to prevent waves washing over the top of the bund; a top course of large stones projecting 4 inches to 6 inehes aids in this. The stones should

PUDDLE WALLS WITH PERVIOUS SURFACE AND SUB SOILS AND PARALLEL AND TRANSVERSE DRAINS

Reg: No. 2549
Copies—1010

OPEN DRAIN OUTSIDE BUND IN CONTINUATION OF TRANSVERSE DRAIN

DRAIN UNDER BUND SHEWING TURF CASING TO PREVENT EARTH GETTING INTO DRAIN

SECTION ON A.A.

GRADIENT OF TRANSVERSE DRAINS UNDER BUND 1 IN 50

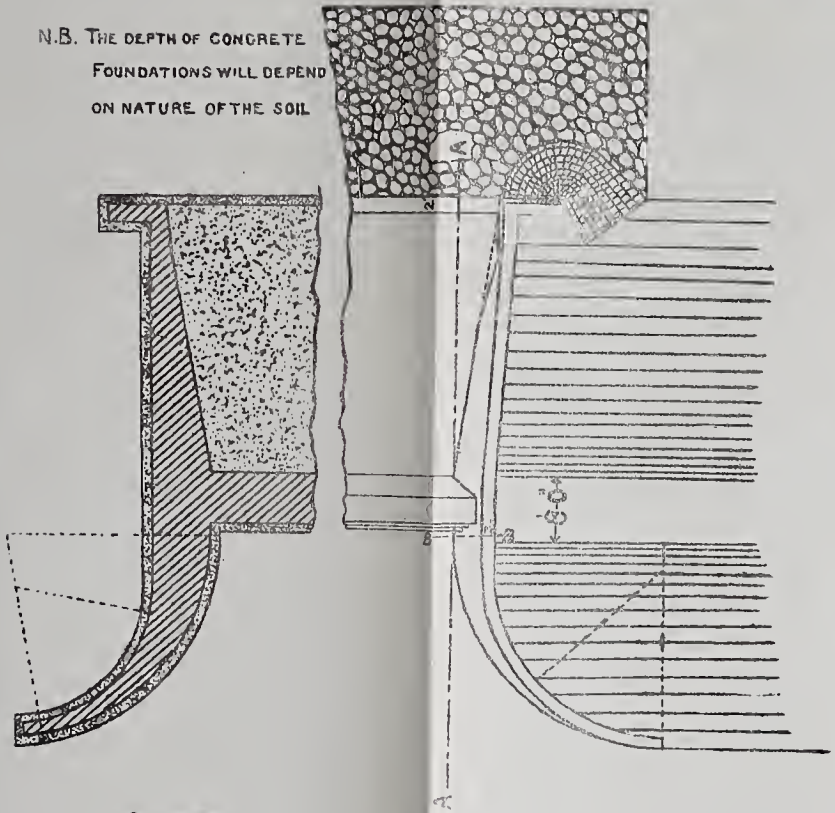
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1896

SURPLUS WEIR WITH WATER CUSHION

SCALE

10 5 0 10 20 30 40 Feet

N.B. The depth of concrete foundations will depend on nature of the soil

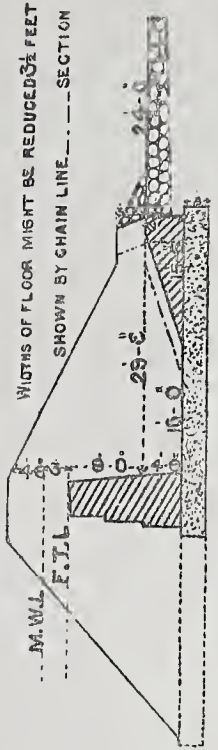


SECTION ON B.B.



SECTION ON A.A

Widths of floor might be reduced 3½ feet as shown by chain line — — — Section



Reg: No. 2503
Copies 1010

Photo Zinco., Survey Office, Madras
1895

be bedded on gravel backing tamped and at least 6 inches in thickness. The outer face of a bund should have a slope of 2 to 1, and should be turfed.

Puddle walls.—There ought to be puddle walls in al cases where the bund is more than 15 feet in height, and also for smaller depths unless the soil and subsoil are very good. The best position for a puddle wall is in the centre of the bund. It has been advocated that the best position is at the face, so that the puddle may always be kept damp, but here it is likely to crack when the bank subsides as it usually does to some extent and it will get dry as the tank level is reduced. The top width of a puddle wall should not be less than 2 feet; the top level should be one foot above maximum water level. The wall should batter 1 in 8 or 1 in 6 according as the puddle is good or only moderately so. No part of a puddle wall should have less thickness than one foot, for each three feet of depth of water against it. The puddle wall should be carried to at least 1 foot below impervious soil, or 4 feet into pervious soil. Where rock is reached, a trench should be cut into the rock with stepped sides, and the clay well punned into it. Clay puddle should be similar to that used for making tiles or bricks. All springs found in any puddle trench should be brought up by an iron or stoneware pipe and carried to one side of the bottom of the bund.

Surplus weir.—The surplus weir of a tank must be capable of discharging the maximum inflow from the catchment area. The difference between the maximum and full tank levels having been fixed, the length of the weir can be ascertained by the formula already given. The surplus weir itself may be formed by cutting a channel through high ground at the end of a bund or by levelling a portion thereof and paving it, and, in order to reduce the velocity, the opening may be made much wider than the result of calculation shows to be necessary. Where the water has to be dropped down, it should be so through as small a height as possible; economy in the design of the weir is then secured. A section of a tank bund and surplus weir (from Mullins' Irrigation Manual) are shown on the accompanying plates. The latter of the two plates shows a water cushion. This is useful in absorbing the shock of the falling water when the height is somewhat great; the depth of the cushion may be determined from the formula—

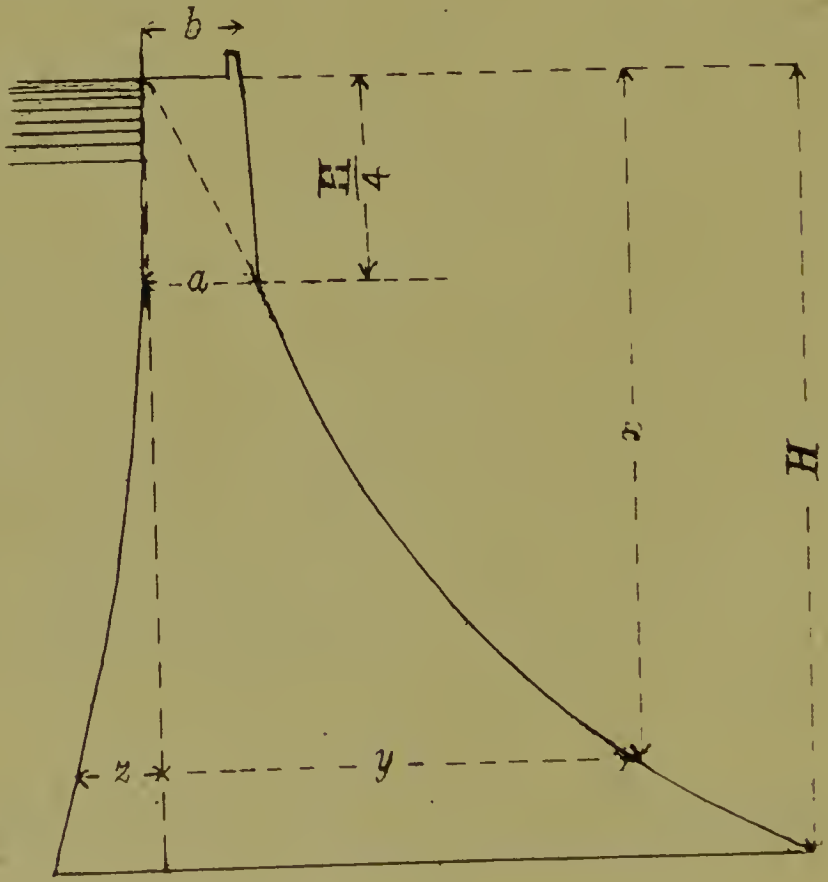
$$D = c\, d^{\frac{3}{2}}\, h^{\frac{1}{3}}$$

where c is a co-efficient varying from 0·75 to 1·25 according as the apron under the weir is solid or otherwise, d height of

the drop and h the depth of water flowing over the weir. Where the apron is level, the width should be from 6 to 8 times $\sqrt{h}$ and the thickness $\frac{1}{4}(d+h)$.

Masonry dams instead of earthen bunds, are sometimes preferable. Special designs are required in all cases where these are of considerable height. The general cross section of a dam is that of a triangle with apex cut off, so as to give a breadth of 7 to 9 feet as a minimum width for the top of the dam. All masonry dams should be founded on hard rock if possible. The design of any dam must take into account the weight of the masonry, and the weight on the foundations, the pressure on any point of the masonry itself, the resistance to sliding, and overturning, &c. Dams may be of masonry preferably, or of brick work. Concrete is an excellent material when carefully mixed and deposited. It is advantageous to lay out high dams in the form of a curve in order to transfer the pressure against the dam to the sides as much as possible. A versed sine of $\frac{1}{20}$th of the chord is a good proportion, as the lateral thrust is not then too oblique to the surface of the ground at either end of the dam.

Formulæ for the cross section of dams.—An ordinary formula used to determine the form of high dams is that of Molesworth—



$$y=\sqrt{\frac{\cdot 05x^3}{P+(\cdot 03x)}}; \quad z=\left(\frac{\cdot 09x}{P}\right)^4$$

where H=height of dam in feet.
x=any depth below water surface.
y=offset from vertical line to outer face at depth x.
z= Do. do. to inner face.
b=width of dam at top=$0{\cdot}4a$
a=width of dam at $\frac{H}{4}$ from top.
P=limit of pressure allowed in masonry in tons per square foot (say 6 to 8 tons).
y must in no case be less than $0{\cdot}6x$.

This gives the requisite stability at the front face when the reservoir is empty, and at the rear face when full, and an excess of stability at the front face when the reservoir is more or less filled, and at the rear face when more or less emptied.

Colonel Pennycuick, R.E., lately Chief Engineer, Public Works Department, Madras, proposes the following formulæ :—

$$y=9\sqrt{\frac{x^3}{P}}$$

P in the above is pressure in pounds on the square foot.

In the following formula he takes into account d the depth of the dam below the plane of calculation, P again being pounds on the square foot.

$$y=7{\cdot}67\sqrt{\frac{x\left\{x^2+\frac{7}{4}\,d\,(x-d)\right\}}{P}}$$

when d exceeds $\frac{x}{2}$ or is more than $\frac{H}{3}$, $\frac{x}{2}$ is substituted for d and the equation becomes—

$$y=9{\cdot}20\sqrt{\frac{x^3}{P}}$$ for pounds on the square foot,

and $y=\sqrt{\frac{0{\cdot}378x^3}{Pt}}$ for tons on the square foot.

For low dams the following dimensions may be adopted :—

Width at top $=0{\cdot}3\ H.$
do. middle$=0{\cdot}5\ H.$
do. bottom$=0{\cdot}7\ H.$

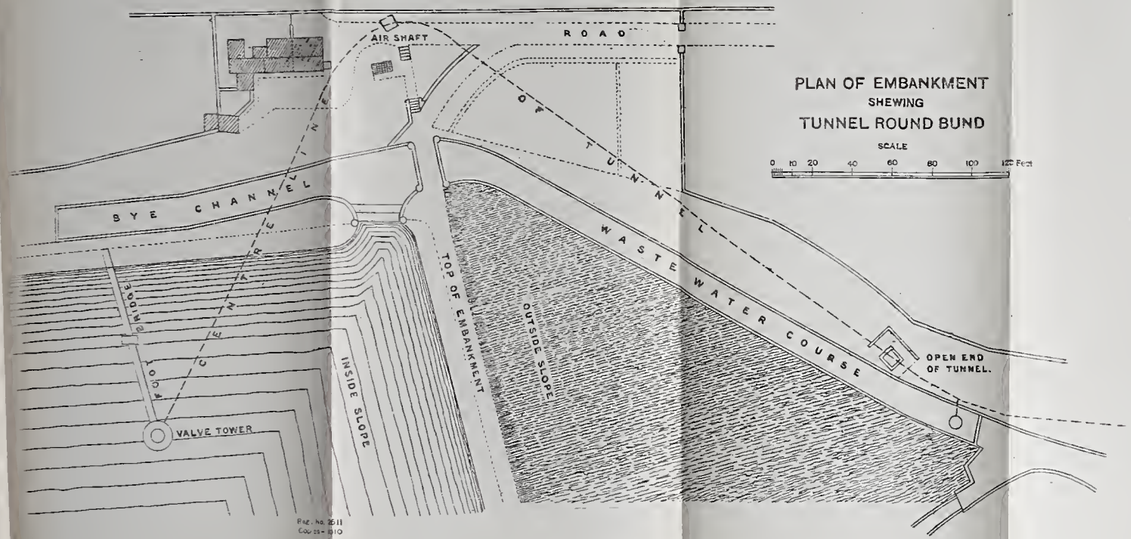
Reservoir outlets.—The position, design and construction of the outlet from a large storage reservoir are among the most serious matters, with which an engineer has to deal, as the safety of the embankment may be endangered and the risk to many thousands of people increased. The outlets

may be of two classes (1) pipes or tunnels through the embankment and (2) through the ground at the end of the embankment; the latter is preferable.

Outlet culverts.—The general practice at one time was simply to lay a pipe from the deepest part of the tank through the embankment, but this is a dangerous practice, as the pipe is likely to be broken, or disjointed by the settlement of the bank, and no line of pipes, unless in very low banks, can resist the pressure due to the settling of the bank, nor can pipes in such a position be repaired without emptying the tank. An improved plan, and one still often adopted is to build a culvert or tunnel of ashlar, or brick work, through which pipes are laid. This, however, though an improved plan, and one often necessarily adopted, is not the best, as there is always a difficulty in building the culvert across the puddle wall, and unequal settlement of the bank and the movement of the puddle before consolidation are likely to crack the culvert and cause it to be flooded. The best plan is to construct the culvert in solid ground round the end of the embankment, by which method all danger due to unequal sinkage of the bank and puddle trench is avoided. When the slope of the ground at the end of an embankment is rapid, this culvert may have to be built as a tunnel; this is one objection to the latter plan but everything considered it is more advantageous than the former. All outlet culverts should be provided with counterfort walls to render, as difficult as possible, the passage of water along the outside of their arches and abutments; the cross section of any culvert crossing a puddle trench should be strengthened for that length.

Valve towers.—It was the practice to simply stop the culvert under the embankment by a wall near the bottom of the inner slope, and the valves at the ends of the pipes were worked from the bund by gearing; they were difficult to repair if they got out of order; an improved plan was to place a valve pit over the culvert in rear of the puddle trench, where the valves were placed. The plan now most generally adopted is the provision of a tower with valves inside and outside the tower so that repairs can be easily executed and the tunnel itself can at all times be entered and inspected.

Pipes through culverts.—Through outlet culverts it is advisable to lay two lines of pipes as the replacement of pipes in a tunnel is always difficult, unless the tunnel is very spacious indeed.



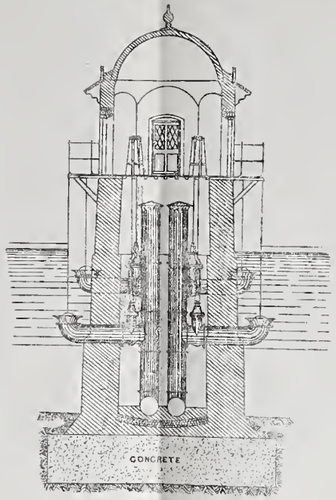
PLAN OF EMBANKMENT
SHEWING
TUNNEL ROUND BUND

SCALE

0 10 20 40 60 80 100 120 Feet

Reg. No. 3611
Cost = 810

CROSS SECTION THRO TOWER



WATER TOWER AND CULVERT THROUGH BUND

SCALE

0 5 10 20 30 40 Feet

LONGITUDINAL SECTION

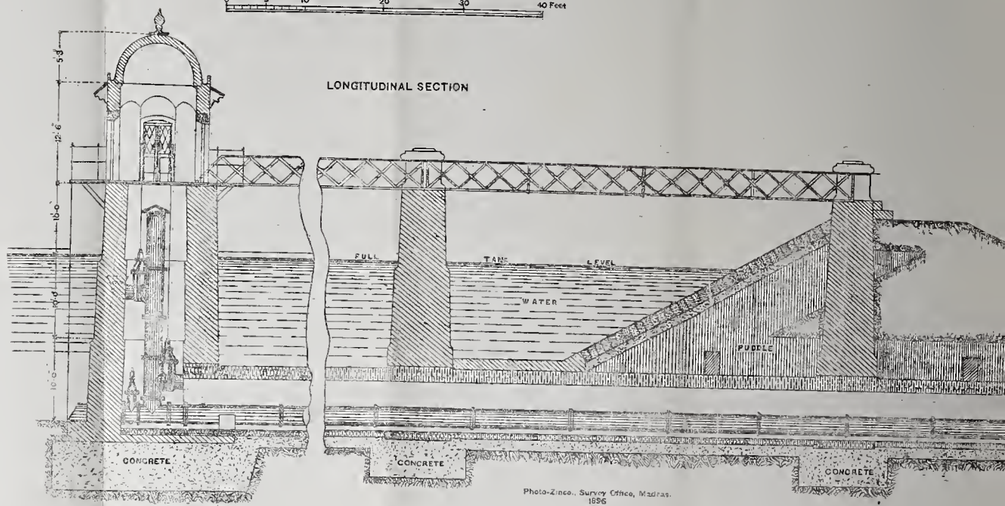
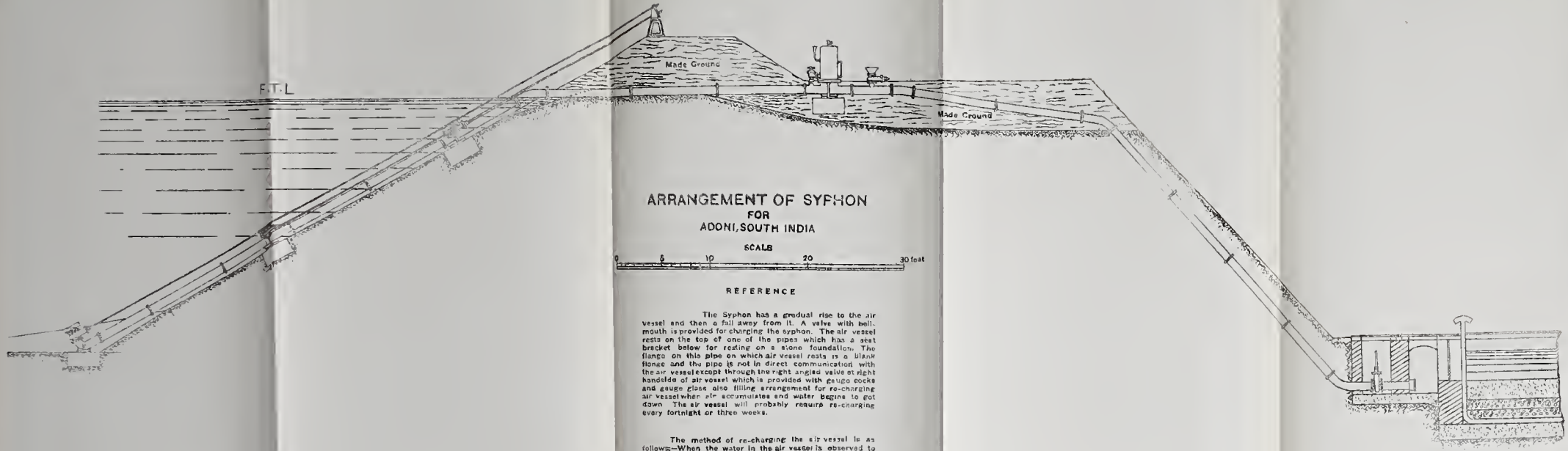


Photo-Zinco. Survey Office, Madras.
1896



ARRANGEMENT OF SYPHON
FOR
ADONI, SOUTH INDIA

SCALE

0 5 10 20 30 feet

REFERENCE

The Syphon has a gradual rise to the air vessel and then a fall away from it. A valve with bell-mouth is provided for charging the syphon. The air vessel rests on the top of one of the pipes which has a seat bracket below for resting on a stone foundation. The flange on this pipe on which air vessel rests is a blank flange and the pipe is not in direct communication with the air vessel except through the right angled valve at right handside of air vessel which is provided with gauge cocks and gauge glass also filling arrangement for re-charging air vessel when air accumulates and water begins to get down. The air vessel will probably require re-charging every fortnight or three weeks.

The method of re-charging the air vessel is as follows:—When the water in the air vessel is observed to be getting low by the level in gauge glass, close the right angled valve, open the valve on the small bellmouth to the left, also the air cock on top. Fill the air vessel full of water, close both cocks and open the right angled valve. The flow through the syphon should be kept as regular as possible. If stopped for any time air is liable to accumulate and stop the syphon action.

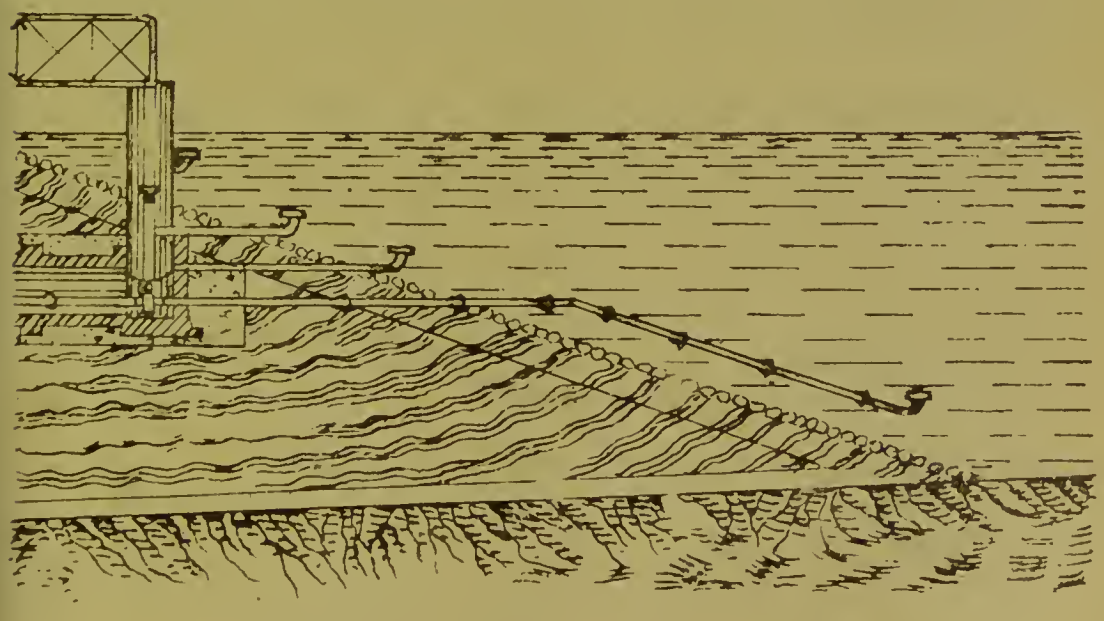
Plan No. 2472
Copies 1010

Photo-Zinco., Survey Office, Madras.
1895

The accompanying plate shows the direction taken by culvert round a bund and a section of a masonry tower with a culvert through the bund.

Syphons.—Syphons are also used for passing water from a tank, and are desirable in some cases, for instance, when an old tank is taken up for the supply of water to a town, and when it is considered risky to cut through an old embankment, or where it would be too expensive to introduce a tunnel outlet; such a method has been used for the withdrawal of the water from the Crusoe tank, Sandhurst, Australia, at Nagpore, Central Provinces and at the Nulla Cheruvu tank near the town of Adoni, Southern India. The syphon adopted at Adoni is shown on an accompanying plate. The method of filling it and keeping it at work is noted on the plate.

It is often advisable, in order to limit the length of the culvert through an embankment and the height of the valve tower, to arrange to draw off the lowest water through the culvert by a syphon pipe thus.—



The accompanying table gives a large amount of information in regard to the proportions, construction and cost of several tanks in the Deccan :—

Abstract Particulars of Storage Works

No.	Name of work.	Data.				
		Area of catchment basin.	Average annual rainfall and estimated proportion of run-off to rainfall.	Fall of river above dam.	Areas commanded.	
					Gross under command.	Net irrigable.
1	2	3	4	5	6	7
	Constructed.	Square miles.	Inches.	Feet per mile.	Acres.	Acres.
1	Mherun Tank, Khándesh.	3·45	...	29·33	...	...
2	Mhasva Tank, Khándesh.	14·00	...	22·00	4,093	3,912
3	Matoba Tank, Poonah.	10·00	$\frac{15·28}{4}$	32·00	10,700	7,133
4	Páshan do. do.	16·00	...	41·00	...	...
5	Patas do. do.	3·00	$\frac{15·85}{4}$	38·00	...	...
6	Ekrúk Tank, Sholápur.	159·00	$\frac{31·57}{4}$	11·00	17,746	16,784
7	Pandharpur Tank Sholápur.	10·00	$\frac{27·97}{4}$	33·00	...	...
8	Maini Tank, Sáttára.	54·00	$\frac{24·24}{4}$	20·00	4,639	3,364
9	Islampur Tank, Sáttára.	2·45	$\frac{28·57}{4}$	42·00	...	...
	Under Construction.					
10	Khirdi Sata Tank, Nasik.	6·40	$\frac{18·81}{4}$	34·00	...	...
11	Pángaon Tank, Nasik.	298·00	$\frac{32·92}{4}$	9·00	52,356	51,548
12	Khas Tank, Sáttára.	1·97	$\frac{139·67}{3}$	61·66	...	...
13	Doni Tank, Dharwar.	24·00	$\frac{22·32}{4}$	33·00	2,440	1,952

onstructed or under construction in the Deccan.

Tank.						
Areas of contours.		Total capacity.	Capacity above sill of sluice.	Depth allowed for evaporation.	Loss by evaporation.	Available storage.
At F.T.L.	At sluice sill.					
8	9	10	11	12	13	14
Millions of square feet.	Millions of square feet.	Millions of cubic feet.	Millions of cubic feet.	Feet.	Millions of cubic feet.	Millions of cubic feet.
6·575	0·050	68·044	67·894	7·00	23·414	44·480
18·348	0·790	160·962	158·571	3·00	27·523	131·048
21·000	0·330	230·000	229·000	4·00	42·000	187·000
6·750	1·000	80·000	73·000	4·00	16·000	57·000
2·000	0·080	15·000	14·750	4·00	4·000	10·750
198·232	12·000	3,330·000	3,310·000	7·00	777·500	2,532·500
8·530	2·000	89·000	79·000	5·00	26·420	52·580
16·570	1·200	195·270	188·590	5·00	33·080	155·510
3·365	0·245	25·230	24·500	4·00	6·730	17·770
7·590	0·930	57·000	52·500	5·00	24·660	27·840
291·960	25·000	5,290·000	4,926·000	Project incomplete.		
3·373	0·333	53·817	52·190	4·00	7·733	44·457
8·885	0·760	140·610	136·410	4·00	20·000	116·410

Abstract Particulars of Storage Works constructed or

No.	Name of work.	Tank—*cont.*			
		Estimated total yield of catchment basin (col. 4.)	Proportion of total yield to capacity (col. 11.)	Capacity (col. 11) per square mile of catchment basin.	Cost of storage capacity (col. 11) per million cubic feet.
		15	16	17	18
	Constructed.	Millions of cubic feet.		Millions of cubic feet.	Rs.
1	Mherun Tank, Khándesh.	...	..	19·679	950
2	Mhasva Tank, Khándesh.	...	...	11·326	421
3	Matoba Tank, Poonah ...	88·75	0·39	22·900	526
4	Páshan do. do. ...	...	...	4·562	2,290
5	Patas do. do. ...	27·60	1·87	4·917	2,317
6	Ekrúk Tank, Sholápur.	2,914·48	0·88	20·818	233
7	Pandharpur Tank, Sholápur.	161·92	2·05	7·900	1,363
8	Maini Tank, Sáttára ...	760·24	4·03	3·492	1,018
9	Islampur Tank, Sáttára.	40·64	1·66	10·000	1,766
	Under Construction.				
10	Khirdi Sata Tank, Nasik.	69·88	1·33	8·203	1,222
11	Pángaon Tank, Nasik.	5,697·74	1·16	16·530	258
12	Khas Tank, Sáttára ...	213·09	4·08	26·492	1,306
13	Doni Tank, Dharwar ...	311·12	2·28	5·684	498

under construction in the Deccan—continued.

Dam.							Waste weir.	
Length of dam.	Maximum height of dam.	Depth, outlet or sluice sill to F.T.L.	M. W. L. above F.T.L.	Top of dam above M.W.L.	Top width of dam.	Description of dam.	Length of waste weir.	M.W.L. above crest.
19	20	21	22	23	24	25	26	27
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.		Feet.	Feet.
1,848	41·20	23·00	3·00	6·00	8·00	Earthen ...	200	3·00
1,494	44·00	22·00	4·10	6·00	10·00	Do. ...	300	4·10
6,095	48·41	29·00	3·00	6·00	6·00	Do. ...	600	3·00
2,750	52·00	31·00	4·00	6·18	6·00	Do. ...	400	4·00
2,900	29·00	16·00	3·00	4·00	6·00	Do. ...	170	3·00
6,940	75·66	38·25	10·00	7·00	6·00	Do. ...	750	10·00
3,500	44·00	18·00	4·50	6·50	4·00	Do. ...	200	4·50
3,370	57·33	31·20	5·00	8·00	3·00	Do. ...	600	5·00
2,892	30·97	15·00	2·00	5·00	6·00	Do. ...	200	2·00
2,465	41·00	15·00	5·00	6·00	6·00	Do. ...	150	5·00
15,100	76·80	30·00	10·38	5·62	8·00	Do. ...	1,500	10·38
1,425	48·64	27·00	3·00	6·00	6·00	Do. ...	200	3·00
452	60·00	34·00	5·40	...	6·00	Concrete with masonry faces.	350	5·40

Abstract Particulars of Storage Works constructed or

No.	Name of work.	Waste weir—*cont.*				Sluices.	
		Top of dam above crest.	Estimated maximum flood discharge.	Discharging power of waste weir.	Estimated run-off per hour.	Area of openings.	Maximum discharge.
		28	29	30	31	32	33
		Feet.	Cubic feet a second.	Cubic feet a second.	Inches	Square feet.	Cubic feet a second
	Constructed.						
1	Mherun Tank, Khándesh.	9·00	2,226	2,226	1·00	0·39	9·31
2	Mhasva Tank, Khándesh.	10·10	9,035	9,034	1·00	3·12	71·37
3	Matoba Tank, Poonah.	9·00	9,680	10,000	1·50	2·35	54·00
4	Páshan -do. do.	10·18	11,564	11,000	1·12	0·55	12·00
5	Patas do. do.	7·00	2,904	3,000	1·50	0·78	14·00
6	Ekrúk Tank, Sholápur.	17·00	43,095	43,763	0·42	24·00	621·00
7	Pandharpur Tank, Sholápur.	11·00	9,680	5,944	1·50	0·78	11·00
8	Maini Tank, Sáttára.	13·00	23,697	24,000	0·68	3·14	86·00
9	Islampur Tank, Sattára.	7·00	1,296	1,305	0·82	0·88	13·00
	Under Construction.						
10	Khirdi Sata Tank, Nasik.	11·00	4,130	4,130	1·00	0·88	22·00
11	Pángaon Tank, Nasik.	16·00	192,309	192,307	1·00	...	...
12	Khas Tank, Sáttára ...	9·00	3,814	3,580	3·00	4·00	102·00
13	Doni Tank, Dharwar.	...	15,488	15,340	1·00	3·12	94·00

under construction in the Deccan—continued.

Cost of works.					Remarks.
Dam.	Outlet of sluices.	Waste weir.	Land compensation.	Total.	
34	35	36	37	38	39
RS.	RS.	RS.	RS.	RS.	
41,371	2,515	17,034	3,603	64,523	Water-supply.
56,682	5,147	962	4,039	66,830	
1,10,422	2,911	1,717	5,400	1,20,450	
1,13,633	10,462	13,466	29,627	1,67,188	Town water-supply.
27,146	2,225	3,426	1,378	34,175	Do. do.
5,38,919	64,406	1,07,106	61,372	7,71,803	
85,652	4,753	16,837	431	1,07,673	Town water-supply.
1,53,113	14,869	21,348	2,654	1,91,984	
33,316	637	1,521	7,882	43,356	Town water-supply.
40,830	1,610	14,720	7,000	64,160	Town water-supply suspended. Famine relief works, 1877.
9,78,382	60,000	71,421	1,63,008	12,72,811	Do. do.
50,967	7,622	8,675	900	68,164	Water-supply for Sátára; small scheme abandoned for larger.
51,655	2,019	13,611	700	67,985	Suspended. Famine relief work, 1877.

THE CONVEYANCE OF WATER-SUPPLIES.

Water-supplies may be divided into three classes:—

(1) Gravitation,
(2) Pumping,
(3) Gravitation and pumping combined.

In the first class, the source is situated at such a level above the town as will allow the water to be delivered in the town at a reasonable height above ground level.

In the second class, the source will be below the town level or only slightly above it.

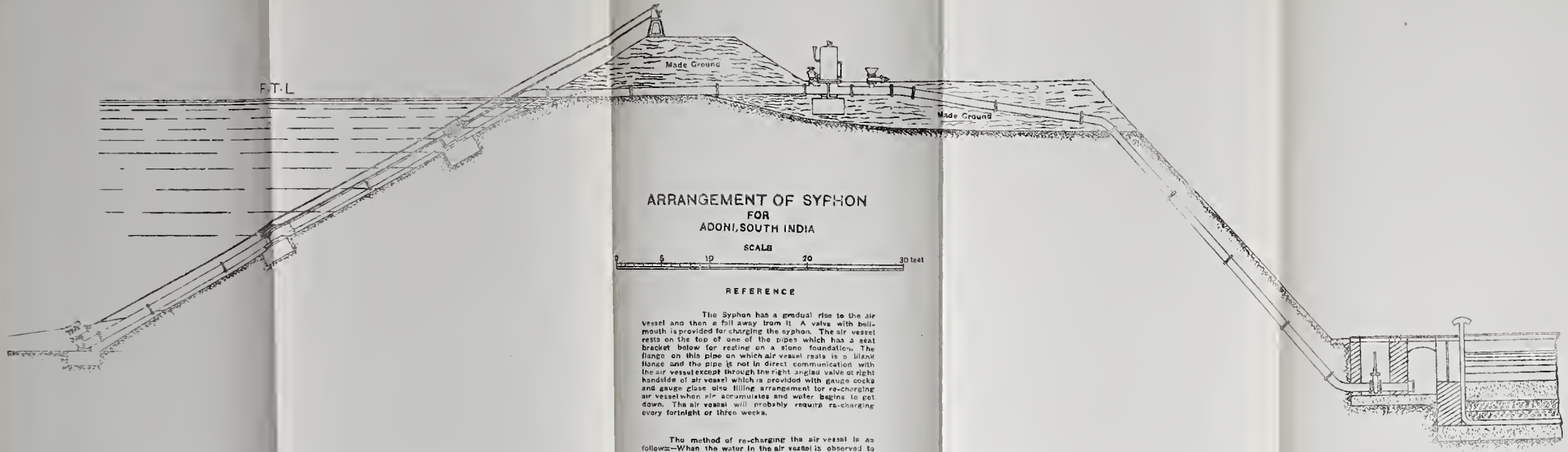
In the third class, the source may be either above or below the town.

The three classes are shown graphically on the accompanying plate.

Conduits.—A pure supply of water is necessarily impounded, or drawn at a distance from the town where it is to be used. It is, therefore, also a necessity to conduct the water to the outskirts of the town in such a manner that its purity may be maintained as far as possible.

Open channels.—In this country it is sometimes necessary to adopt an open channel in order, when the source of supply is at a distance, to save expense. Such a channel must be thoroughly fenced, protected against pollution by drainage, or otherwise, but it is almost impossible to keep such a channel free from invasion by animals of various description. An open channel also, unless with considerable gradients, is apt to be filled with aquatic plants, weeds, &c.; fish, frogs, &c., will find a home in its waters; it is therefore the least satisfactory description of conduit.

Masonry conduits.—Where the quantity of water to be dealt with is moderate and where every chance of all but a moderate water pressure on the conduit can be avoided, stoneware (or even earthenware) or cement pipes may be found suitable. Where the quantity is large, and the obtainable gradient a moderate one, resort must be had to culverts of brick or masonry. These are unsuited to any pressure from within, and should never run full. The cross sections of several examples of such conduits are to be found in the diagram following. The discharges, through such conduits if open channels, may bo determined by methods already stated, and if through closed conduits, by the formulæ or tables of discharges applicable to sewers (*seq.*)



ARRANGEMENT OF SYPHON
FOR
ADONI, SOUTH INDIA

SCALE

0 5 10 20 30 feet

REFERENCE

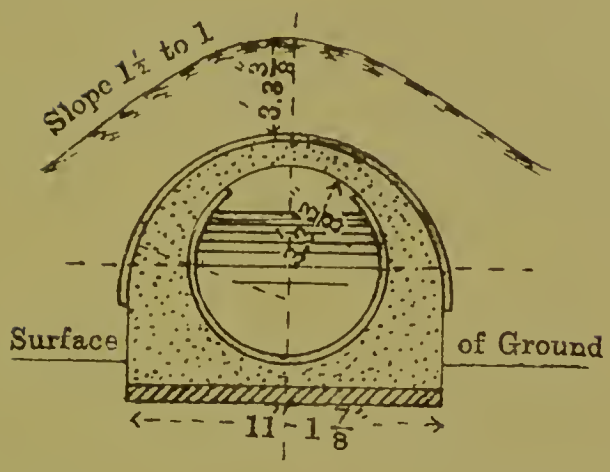
The Syphon has a gradual rise to the air vessel and then a fall away from it. A valve with bell-mouth is provided for charging the syphon. The air vessel rests on the top of one of the pipes which has a seat bracket below for resting on a stone foundation. The flange on this pipe on which air vessel rests is a blank flange and the pipe is not in direct communication with the air vessel except through the right angled valve at right handside of air vessel which is provided with gauge cocks and gauge glass also filling arrangement for re-charging air vessel when air accumulates and water begins to get down. The air vessel will probably require re-charging every fortnight or three weeks.

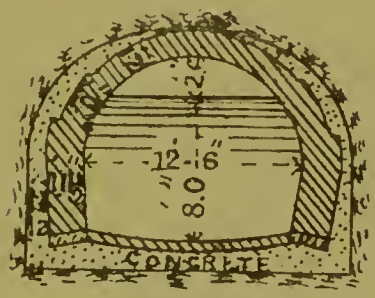
The method of re-charging the air vessel is as follows:—When the water in the air vessel is observed to be getting low by the level in gauge glass, close the right angled valve, open the valve on the small bellmouth to the left, also the air cock on top. Fill the air vessel full of water, close both cocks and open the right angled valve. The flow through the syphon should be kept as regular as possible. It stopped for any time air is liable to accumulate and stop the syphon action.

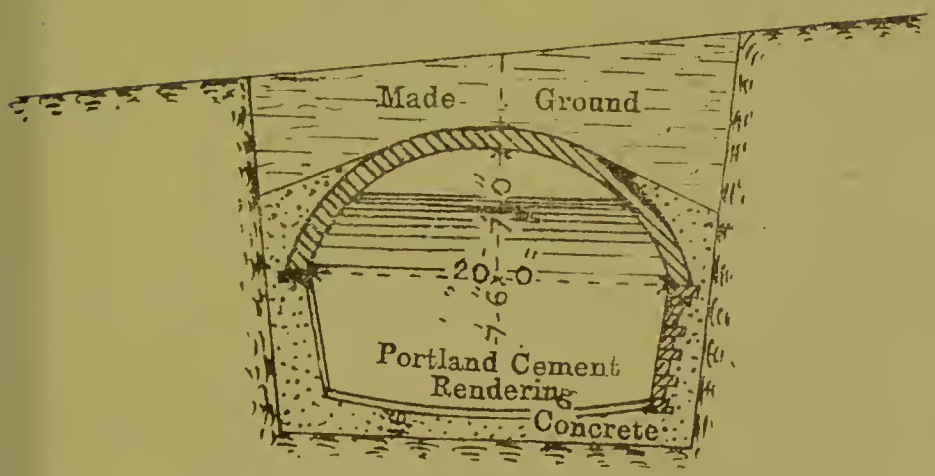
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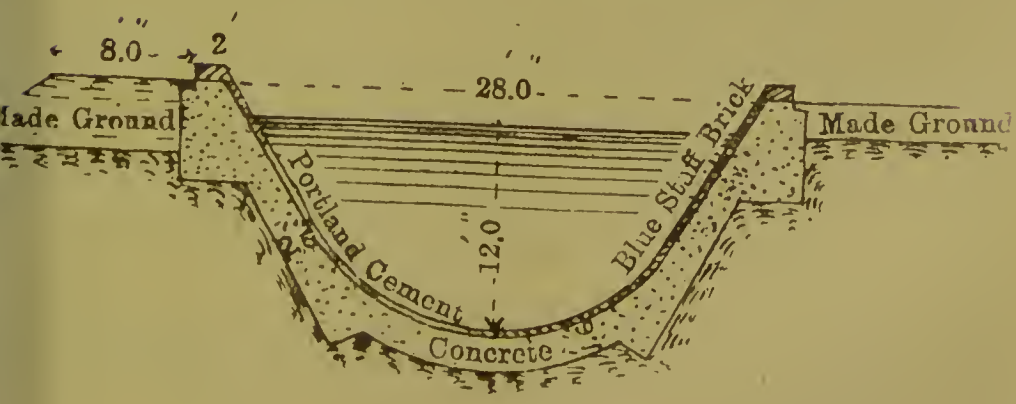
Photo-Zinco., Survey Office, Madras.
1895

CONDUITS.


Slope 1½ to 1
3.3
3/8
Surface
of Ground
11-1 7/8


12-6
8.0
CONCRETE


Made Ground
20-0
Portland Cement
Rendering
Concrete


8.0
2
28.0
Made Ground
Made Ground
Portland Cement
Concrete
Blue Stuff Brick
12.0

Iron conduits.—Iron pipes form the best description of conduit, as they do not require to be laid at any particular gradient, but may follow the natural slope of the country, and be laid in a more direct line than would be possible with conduits of either of the former description. The water in these may be under pressure, and the size of such conduits is then to be determined in a manner similar to that used for iron pipe discharges and on principles to be hereafter enunciated.

THE PURIFICATION OF WATER.

Works necessary.—In any system of distribution of water-supply unless the water has been naturally filtered, filters and compensating or clear water reservoirs are desirable ; in most cases they are necessary. A subsiding reservoir is also a necessary adjunct, if the water to be used is such that it yields a deposit as would soon tend to clog up the filters. These works will now be described and illustrated.

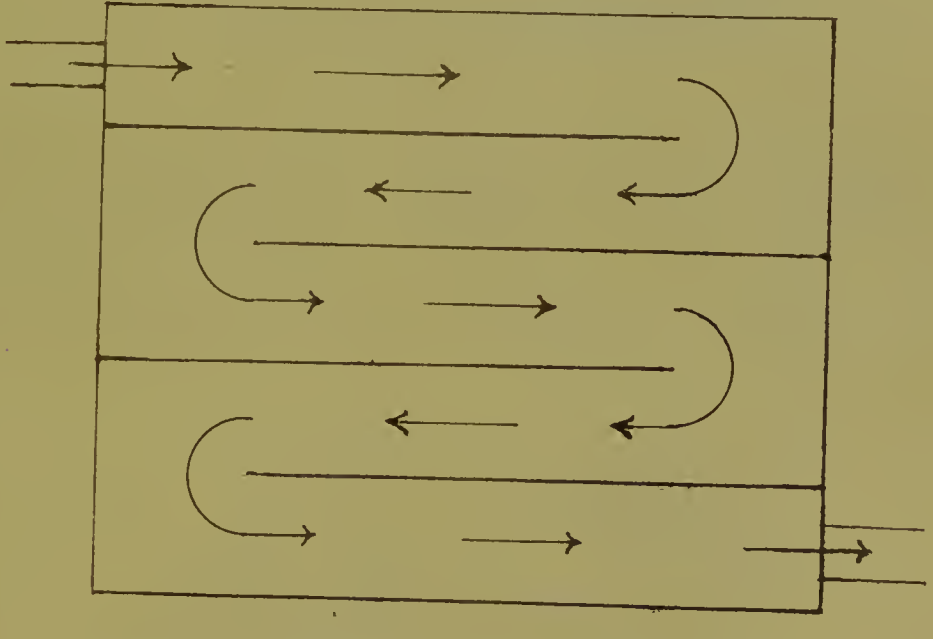
Settling tanks.—The area of subsiding reservoirs or settling tanks required, depends on the state of the water when admitted to them. Water may hold in suspension very large quantites of material ; if this is of a heavy description the deposit will take place much more quickly than with material of a lighter class. The proper area of a subsiding reservoir must, therefore, be determined in reference to the amount and specific gravity of the material in suspension. The time taken to deposit such matters must be a matter of experiment or experience.

Constant v. Intermittent settlement.—Settlement may be conducted either on the constant or alternating system. In the former system the water is continually flowing in at one end and out at the other end of the settling reservoir, the reservoir is thus a canal with a low velocity ; with alternating or intermittent settlement, two reservoirs at least are necessary, water being drawn off from one reservoir, while it is admitted to another. The depth of settling reservoirs is from 8 to 15 feet ; it is not always possible to arrange the levels of the filter beds, so that the water can be drawn down to within a few feet of the bottom of the settling reservoirs. If it is possible to draw down only a few feet below the maximum water level, pumps should be provided for emptying. The lower two or three feet should never be drawn to the filters.

There is a difference of opinion as to whether constant or intermittent settlement is best ; each particular case should, it is thought, be decided on its own merits ; the *pros*

and *cons* are these. With the constant system there is longer time for settlement *with the water very nearly at rest* than there would be with the same capacity of reservoir under the intermittent system, but on the other hand, *perfect* rest is much more favourable to settlement than even a very small velocity, and certainly in this country it will be preferable to adopt the intermittent system, as likely to be more perfectly worked. With the intermittent system there is a tendency, when the water is drawn down very low, for the deposit to be moved from near the inlet to the outlet; this is not so likely under the constant system.

Design of settling reservoirs.—The best form for a settling reservoir is a rectangle with the length several times the breadth and where this can be divided, so that the water travels this length several times over, that form is still more efficient:—

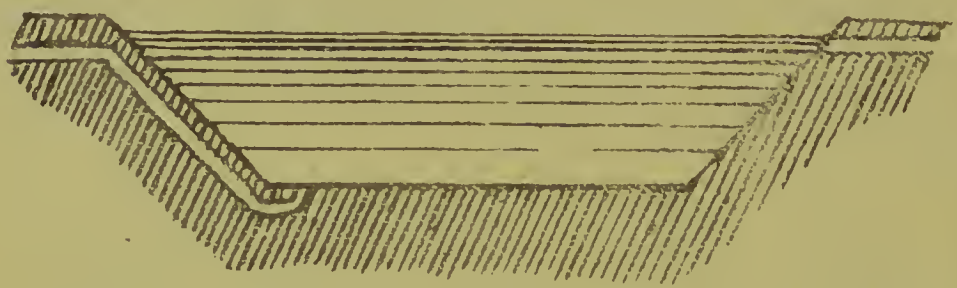


A circular form is the most economical, a square form more so than a rectangular form, but with two reservoirs close together, this latter form for the outer boundary of two adjacent reservoirs can be advantageously adopted. In section, the reservoir may have slopes 2 to 1 or 3 to 1, and should be revetted, or lined with such material as will allow the banks to be cleansed. The floor should have a slope of 1 in 200 towards a drain for which a slope of 1 in 300 is sufficient.

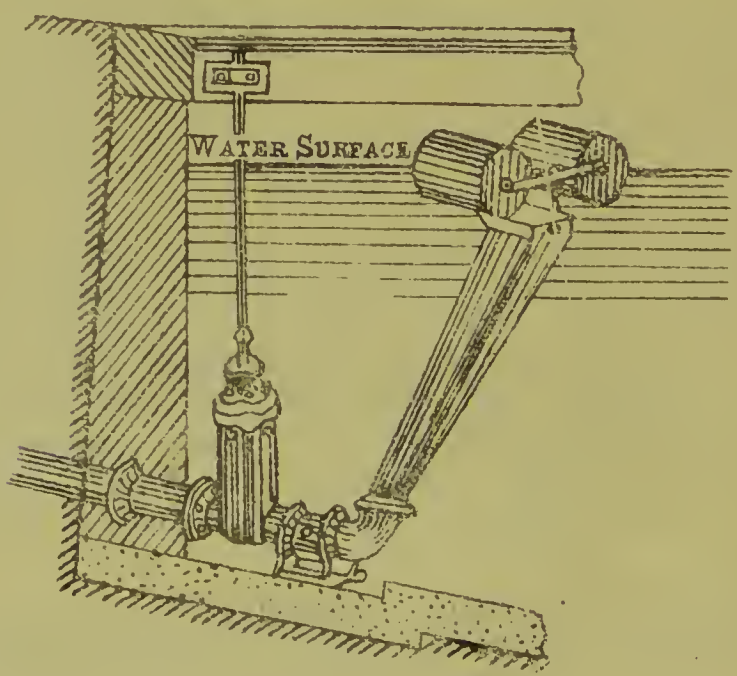
Position of inlets and outlets.—The selection of the proper position for inlets and outlets of subsiding reservoirs requires attention. There are four relative positions:—

(1) Both inlet and outlet at top of reservior.
(2) Both inlet and outlet at bottom of reservoir.
(3) Inlet at top and outlet at bottom.
(4) Inlet at bottom and outlet at top.

The best position is (4) because if the entering water is colder than that already in the reservoir, it will incline to remain at the bottom and force up the purer water, if it be warmer it will however tend to rise and take a more direct course towards the outlet, but having to pass through a larger body of water from this position, its temperature will soon be assimilated and that tendency cease : the position is illustrated thus :—



It is evident however, under this system, that water can be drawn down only a short distance from the top level ; a modification is therefore necessary, if the intermittent system (wherein the water is drawn down to within two or three feet of the bottom) is in force ; a stand pipe with valves at different levels or a floating pipe must be used. The latter is illustrated in the following diagram :—



The water until it appears turbid is drawn down and passed to the filters; the remainder must be passed off to waste. The cleansing of subsiding reservoirs may take place at any interval, the frequency or otherwise having reference to the nature and amount of the deposit.

From the settling tanks the water is passed to the filters.

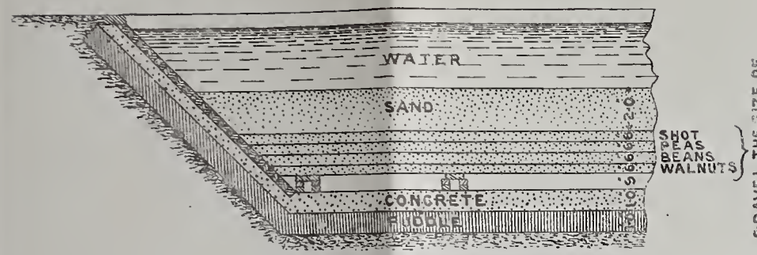
Principles of filtration.—Before entering on a description of filter beds, it is advisable to enunciate the principles upon which filtration depends,—a matter which is generally very imperfectly understood. The latest experiments made are those in relation to filters in connection with the water-supply of Berlin, and the results and conclusions arrived at, which are but a corroboration of less recent conclusions, may be stated succinctly as follow:—

Filtration, a biological process.— The operation of filtering was for a long period deemed an entirely mechanical operation, for sifting out visible matters in suspension, the result being tested merely by the aid of the eye. Subsequently chemical analysis was resorted to, and this resulted in a large reduction of the speed of filtration which is now generally 4 to 6 inches in depth of water per hour. The application of bacteriology to the testing of water gave, however, a clearer conception of the changes to which water is subjected in passing through sand filters and showed that, for the water from each particular source, there is a rate of filtration particularly applicable. If the sand of filters is of a fairly uniform grain, the volume of the interstices is about 33 per cent. Water abounds with micro-organisms and in some waters the bacteria of cholera, typhus, or tuberculosis may be present. It is therefore desirable to remove as many bacteria as possible before the water is available for domestic supply. Sand, when closely packed, has interstices between the grains of $\frac{1}{10}$th of a millimetre (0·00393 of an inch), whereas bacteria are of a size from $\frac{1}{600}$th to $\frac{1}{200}$th of a millimetre (0·000065 to ·000196 of an inch) so that they can easily pass through the channels amongst the sand grains. The longer the channels the slower the rate, and the greater the chance of arrestment, but economic considerations limit the depth of sand and flow of water so that the former is limited to from 2 to 3 feet, and the latter to 4 inches per hour. Under such conditions nevertheless sand filters arrest the bacteria as shown by the following analysis of 1 kilogram of sand by Koch's process:—

	Colonies of bacteria capable of further development. Millions.
At the surface	734
At 4″ below surface	190
At 8″ do.	150
At 12″ do.	92
At 24″ do.	60

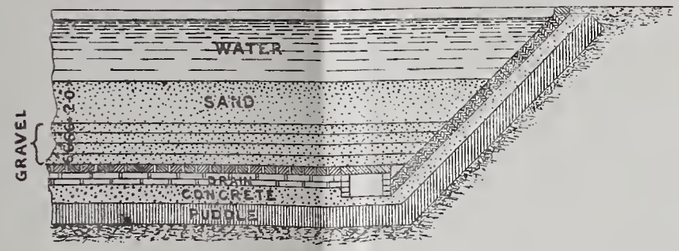
The grains of sand examined were moreover found to be covered with a thin skin consisting in part of bacteria. The sand referred to had been some ten years in use, and it was thought that clean sand would give better results. This, however, was found not to be the case. Investigation, chemical and bacteriological, followed for two years with different classes of sand and waters, and it was found that the effect of sand filtration was due very slightly to chemical action and almost wholly to the labours of the bacteria themselves. The sand was found to be a matrix on which the bacteria fastened themselves, and if the water is insufficient in force (that is of moderate speed) to carry the bacteria away, the bacteria carry on the conversion of organic substances liable to putrefaction in water into inorganic matters. Sand filtration is therefore a biological process. There are many particles of matter in river and tank waters, which in addition to bacteria, deposit themselves on the surface of sand, and form a continuous covering, the pores of which are finer than the sand pores. A coating is also produced by algae abounding in such waters. Through such coating the water percolates, and on it, and in it the bacteria settle, reinforced in numbers, by each drop of water passing through. Multitudes pass through, and in, and on to the sand where they adhere, and continue their labours on all water passing them, and the colonies are, as already stated, most dense at the surface. The removal of organic matter or the conversion of organic into inorganic matter takes place therefore with the greatest intensity near the surface, and it is found that below 12 inches in depth the reduction of the oxidation is extremely small, there not being sufficient food in the lower strata to support a large bacteria population. It is therefore deduced that no equivalent advantage is secured by an increase in the thickness of the sand layer. To prevent the bacteria being washed down into the lower layers it is necessary to increase the head of water on the sand very gradually, and an increase to certain limits in this way is not injurious; probably 2 feet is a maximum

FIG.NO 1



NOTE Fig 1 shews a Longitudinal Section (a portion) and Fig 2 the cross section (a portion) of one Filter Bed.

FIG.NO 2



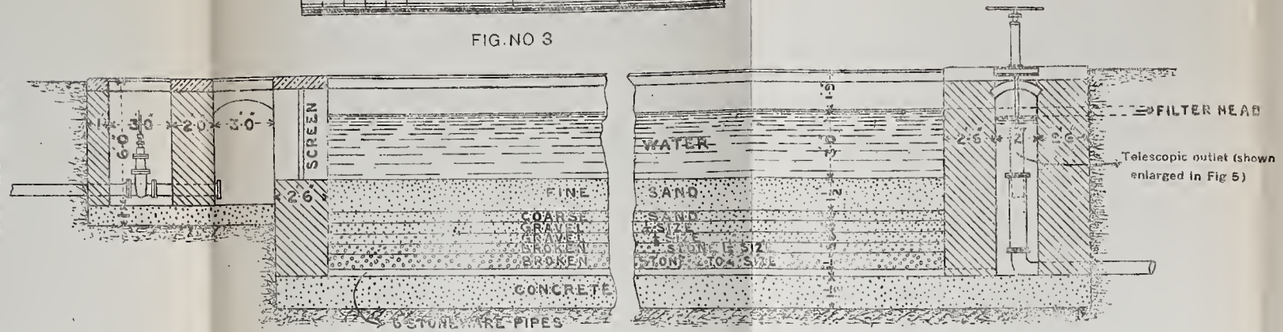
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SECTIONS OF FILTERS

SCALE

0 1 2 3 4 5 10 15 20Feet

FIG.NO 3



NOTE Figs 3 and 4 shew cross and Longitudinal Sections of different filters

FIG.NO 4

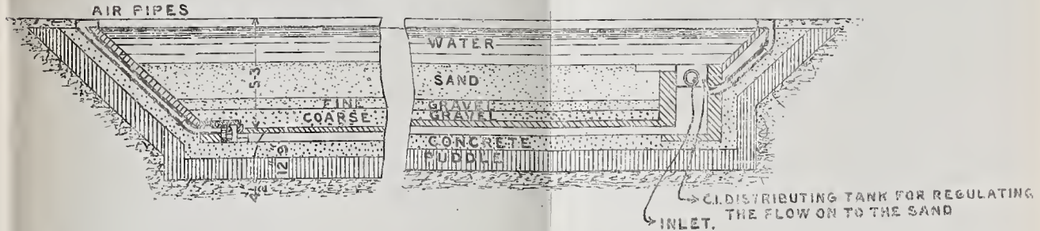


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1896

TELESCOPIC OUTLET

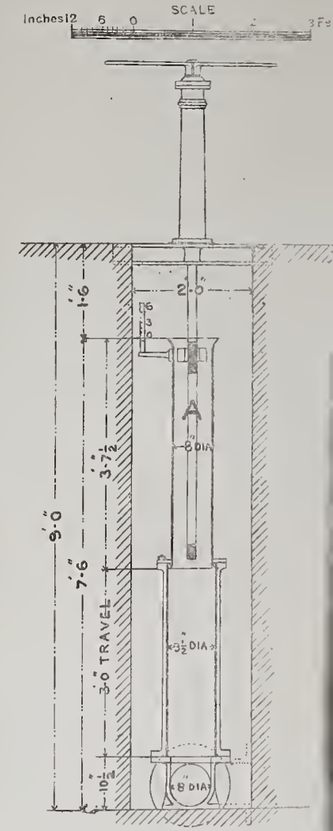


FIG.NO 5

difference of depth between the level of water in the filters, and the level of that which has passed through; the proper rate of filtration is from 4 inches (preferably) to 6 inches of depth of water per hour, or 450 gallons to 675 gallons per square yard per diem.

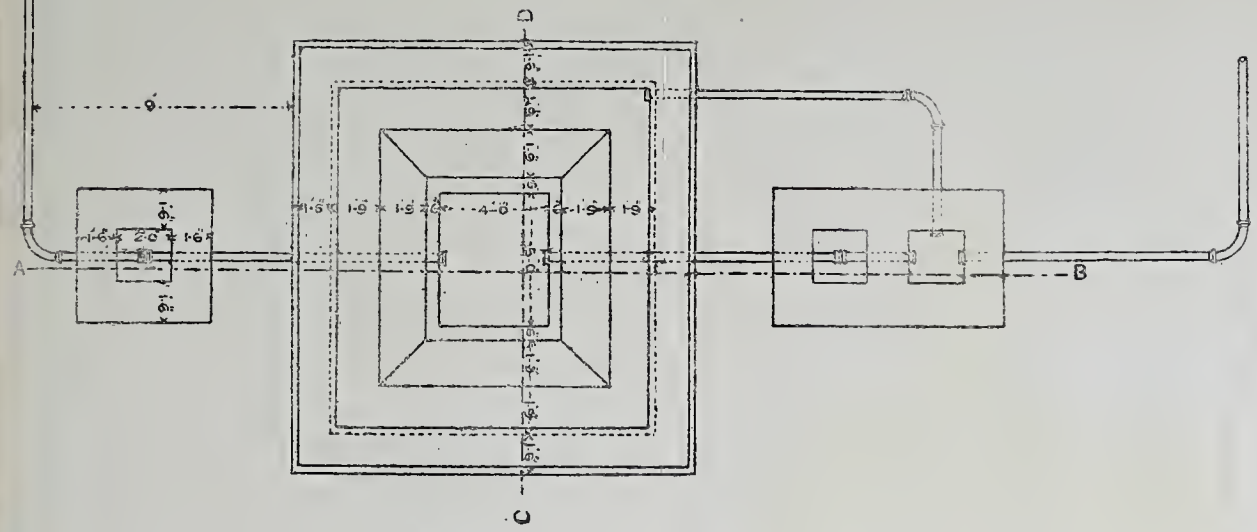
Filter designs.—The plate accompanying shews sections of filters of varied design. One point to be carefully considered is the manner of admission of the water to the filters, and this should be so arranged that, when the filter is first filled, the sand should not be liable to be disturbed. Filters ought to be filled up, if possible when completely de-watered, from below. Arrangements should also be made so that the 'head' of the filter can be altered as necessary. One plan of doing this is shown in figs. 3 and 5 of the above plate, the pipe marked A being capable of being raised or lowered as required; where expense has not to be considered, the best arrangement is an automatic one which maintains always the same rate of flow through the filters.

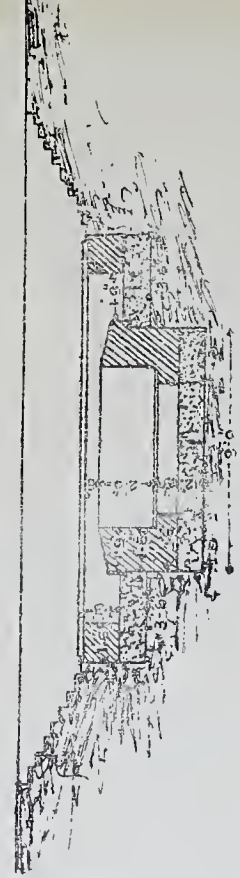
The floor of a filter bed may be made to slope a little but this is not absolutely necessary, as it is the static head that makes the water flow through the filter bed drains. The drains, unless discharging into an open channel (see fig. 3 of the above plate), must be ventilated, and these ventilators should be carried to ground level (see fig. 4). The sides of a filter bed may be either vertical or sloping. With sloping sides, the mean area of the sand bed is the area of the filter bed to be considered in relation to the flow and in the determination of the size of the bed. Where water is admitted to the filter bed direct from an impounding reservoir, a screening arrangement such as that shown in fig. 3 of the above plate is advisable, unless screens have been provided in the offtake tower or other outlet.

Filter-head. — It should be noted that it is not an unusual error to suppose that the depth of water over the sand affects the rate of filtration; that rate depends on the difference of the level inside and outside the filter only and *not* on the depth of water over the sand (see fig. 3). Some persons also consider that this latter depth has considerable effect on the temperature of the water; this, however, is not so; for instance, if filtration is proceeding at the rate of 4 inches per hour or 8 feet per diem and only 1 foot depth of water over the sand, it will be exposed to the heat of the sun for three hours; if there be 3 feet of water there will be three times the quantity

of water to be treated, but it will be exposed to the sun for nine hours. It is evident therefore that, unless the dopth can be made such that the rays of the sun cannot penetrate the lower layers (and this is impracticable 8 or 9 feet being required), there is not much advantage in having a great depth. Engineers generally, however, favour a depth of about 3 feet.

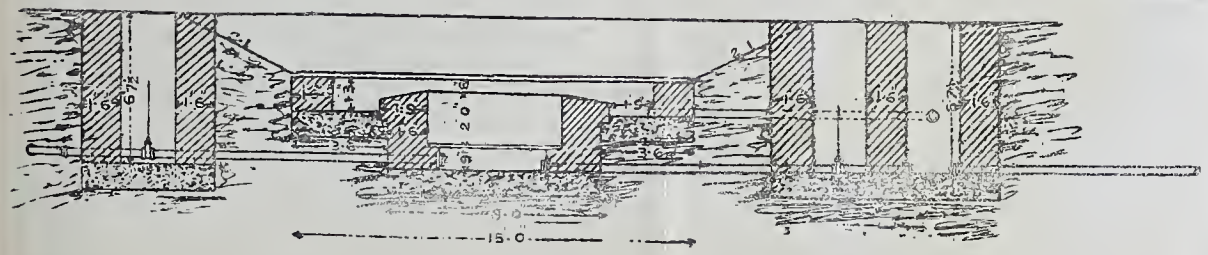
Cleansing filters and sand.—It is necessary, in order to carry on filtration at the rate, and without any excess over the head, already stated, to clean the sand from the filters. When a filter has been in action some weeks, the organic matter collected on the sand surface deprived of its free movements in water may die and in hot weather putrefy. It is a sign of advanced putrefaction when spongy masses float on the surface of the water of the filters, and it is then time to stop the filter and clean it. This is done by allowing the water to run away by the scour pipes; after the water has been drawn down to a level of 1 foot below the sand, and discharged as usual, a sheet of sand ought to be removed equal to $\frac{1}{2}''$ in thickness. The surface is then raked with toothless wooden rakes. After the filter has been so treated, it should remain exposed to the atmosphere for some time. The sand so removed is not at once replaced, as this would involve too much labour, and it is usual to remove the sand before replacement until its thickness is reduced by 50 per cent. or, say, to 1 foot. No sand is so clean that it does not require washing, and even if clean sand were always at hand and available, it should be so before use. The usual practice is to clean the sand removed from the beds using it over and over again, and this may be done by means of a sand-washing box (plate accompanying). The sand is placed in the box and water is admitted from below; a pressure of 7 to 8 feet is the best. The sand is stirred up and the entering water overflowing carries off the impurities in the sand; when the water flows away quite clear tho sand is removed and stored (in one corner of the filter bed if possible) ready for use. In the diagram accompanying is a sand-washing apparatus known as "Walker's Patent." tho water being introduced from below through flexible pipes attached to a main, the buckets can be tipped when the sand is clean. These buckots are placed in batteries of such numbers as required, and a small truck running alongside the battery collects the clean sand and conveys it to the filters. A third plan is to construct a narrow shallow canal into and out of which water flows continuously; the sand is put in near the





SAND WASHING BOX

SECTION ON A.B.



SCALE





outlet end and raked up towards the inlet end. The rate of flow and raking of the sand should be so regulated that no sand is driven out of the outlet and that before the inlet is reached the water passed through the sand is quite clear. A canal 30 feet long is sufficient for populations up to 100,000; for small populations the box plan is the best. The water used for sand-washing should be filtered water, or at any rate, clean water purified in some measure. Filter beds, besides the ordinary cleansing above described, should at intervals of six months, a year or two years as required, be thoroughly emptied out.

Results of cleansing filters.—Filters to a minor degree give less satisfactory results after cleansing than before cleansing. On restarting a filter the water should be filled into the normal depth and allowed to stand 24 hours. If the filter has been merely cleaned, it will, at its normal speed, deliver satisfactory water on the third day, but if fresh sand has been added not until the tenth day.

Area and number of filter beds.—To provide for cleaning, one filter bed, at least must always be out of action and the filter area must be divided among two or more independent beds and then one additional bed should be provided as a surplus. The greater the number of equal divisions the less will be the surplus area to be provided and, on the other hand, each division adds to the cost so that both convenience and finance are factors in controlling the design. The division may be approximately as follows:—

Population.	Number of gallons per head.	Gallons per diem.	Actual filter area required.		Suggested number and size of filters.	
			SQ. YDS.	SQ. FT.	NO.	SIZE.
5,000 ...	7.5	37,500	84	756	3	20 × 20
	10·0	50,000	111	999	3	22 × 22
	15·0	75,000	166	1,494	3	28 × 28
7,500 ...	7·5	56,250	125	1,125	3	24 × 24
	10·0	75,000	166	1,494	3	28 × 28
	15·0	112,500	250	2,250	3	34 × 34
10,000 ...	7·5	75,000	166	1,494	3	28 × 28
	10·0	100,000	222	1,998	3	32 × 32
	15·0	150,000	333	2,997	3	38 × 38
15,000 ...	7·5	112,500	250	2,250	3	34 × 34
	10·0	150,000	333	2,997	3	38 × 38
	15·0	225,000	500	4,500	4	38 × 38

Population.	Number of gallons per head.	Gallons per diem.	Actual filter area required.		Suggested number and size of filters.	
			SQ. YDS.	SQ. FT.	NO.	SIZE.
20,000 ...	7·5	150,000	333	2,997	3	38 × 38
	10·0	200,000	444	3,996	4	37 × 37
	15·0	300,000	666	5,994	4	45 × 45
30,000 ...	7·5	225,000	500	4,500	4	38 × 38
	10·0	300,000	666	5,994	4	45 × 45
	15·0	450,000	1,000	9,000	4	55 × 55
40,000 ...	7·5	300,000	666	5,994	4	45 × 45
	10·0	400,000	888	7,992	4	50 × 50
	15·0	600,000	1,332	11,988	4	65 × 65
50,000 ...	7·5	375,000	840	7,560	4	50 × 50
	10·0	500,000	1,111	9,999	4	58 × 58
	15·0	750,000	1,666	14,994	4	70 × 70

Rules for working filter beds will be found in an appendix to this chapter.

Other systems of purification.—There are systems of purification other than that of filtration referred to above, one of the chief systems being purification by what are known as revolving purifiers. These are large cylinders which are caused to revolve. The cylinders are partly filled with spongy iron or cast iron borings, the latter being preferable. The water is introduced into the cylinders at one end and drawn off at the other after a contract of about $3\frac{1}{2}$ minutes with the iron. It is stated that impure waters purified by means of iron will prove safer for dietetic purposes than even good deep well or spring water; because after treatment the water can be preserved in covered reservoirs, whereas wells or springs may become contaminated.

Covered service reservoirs receive the water from the filters; they serve to compensate for the difference between demand and supply. The size of a covered service reservoir is fixed by the relation between the maximum demand and the average supply.

Generally in a town it may be taken that one half the supply is required in six hours, or from 6 A.M. to 9 A.M. and 3 P.M. to 6 P.M., or that the demand is at times double the average. As in six hours only one quarter the supply would be received in a reservoir while one half is demanded, it

must hold at least a quantity equal to one-fourth of the day's demand. It is desirable, however, to make it hold one-third and in some cases such reservoirs are designed to contain one half and up to one day's demand. When water is not received into the reservoir at night, for instance, when water is pumped only during the day of 12 hours, the reservoir should contain at least one day's supply and more if duplicate pumping machinery is not available.

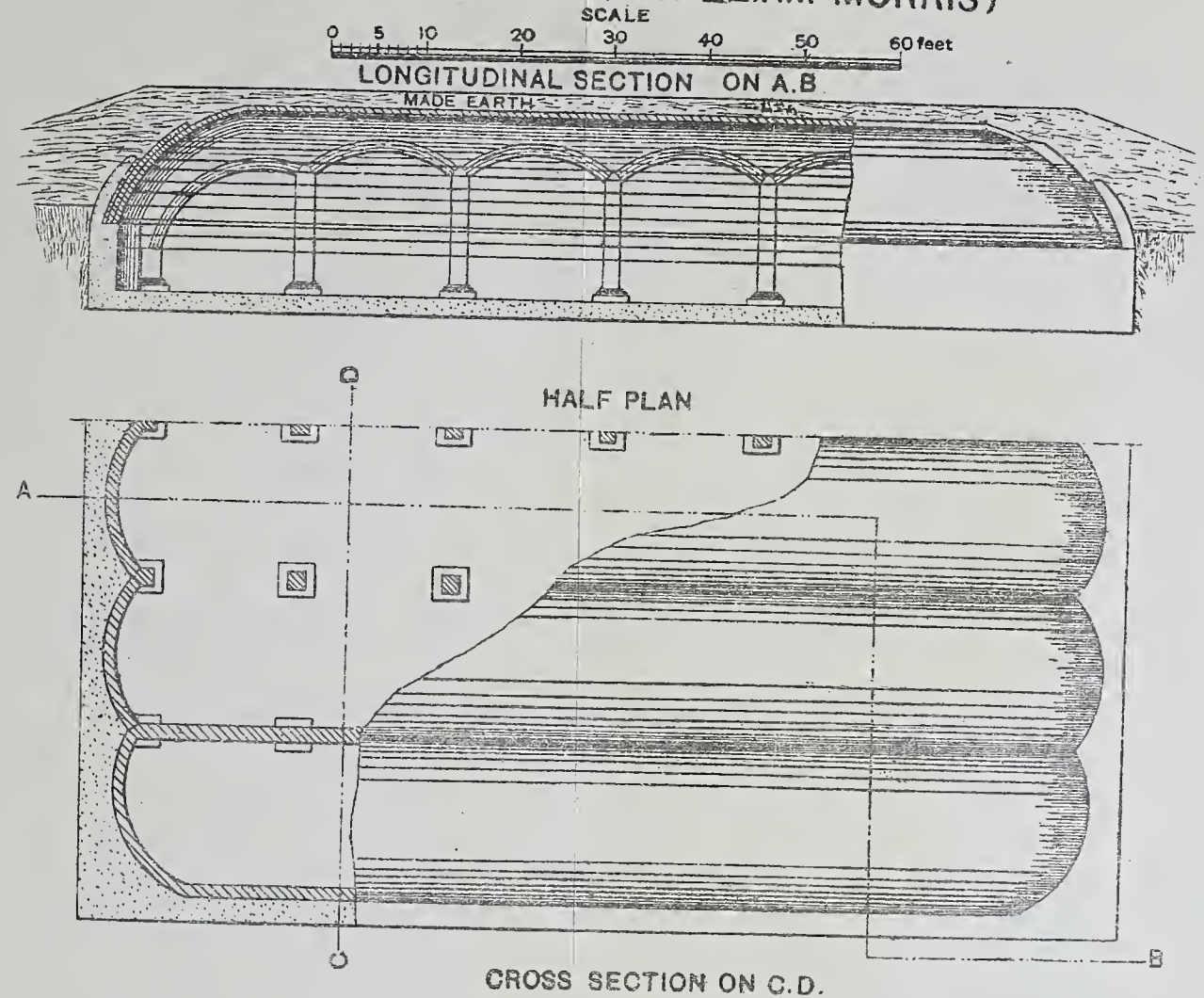
Compensating service reservoirs.—On the plate accompanying is shown the design of a compensating service reservoir. Such reservoirs should be covered because of liability to be fouled by birds dropping matter into them, by air impurities and in order to keep water cool. The following are points in the design and construction of such a reservoir as should be approximated to:—

It should be built on a level ground and homogeneous soil. The design should be so arranged that the earth from the excavation is utilized in covering the reservoir and forming the necessary embankments; the depth of excavation therefore depends on the slope given to the embankment. If a slope of $2\frac{1}{2}$ to 1 is adopted, an excavation about 11 feet deep will furnish an embankment 13 feet above ground line giving 2 feet of earth over the reservoir roof.

The work should be commenced by digging trenches 7 feet wide and 11 feet deep for the reception of the outside walls (it will be convenient to designate the outer walls which are parallel with the vaulting, the side walls, and those at right angles to the vaulting, the end walls). The bottom of these trenches should be covered with 18 inches of concrete, on which concrete side walls, 4 feet thick, and 7 feet 6 inches high, should be constructed, the concrete being rammed between the moulds for forming the internal face and the external earth. The end walls should be similar, except as regards the internal face which should have six curved bays, the radius of the curve being 11 feet 6 inches. As soon as the concrete in the walls has set, the moulds should be taken down, and the surface rendered with Portland cement mortar worked with the trowel, till it becomes hard and smooth, and then finished with a film of neat cement worked to a fine polish.

If the ground be firm, the toe of the wall, supported by the internal earth, will be sufficient to sustain the wall against external pressure without strutting; but care should be taken not to load the ground outside the reservoir by the

MODEL RESERVOIR (WILLIAM MORRIS)



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1896

premature construction of the embankment. The internal earth or dumpling should now be removed down to the level of the toe of the wall, but in removing the earth below this level, which should be done piecemeal, the layer of concrete forming the floor of the reservoir should be at once substituted, the thickness of which, 2 feet, would when set be ample to resist any ordinary external pressure tending to thrust forward the toe of the wall.

The floor having been laid, the brick piers for supporting the vaulted roof should be built on it. These are 1 foot 10½ inches square on plan, and 16 feet 8 inches from centre to centre in each direction. From these piers, at 13 feet from the floor, spring the arches which support the vaulting; the arches in the centre have a radius of 11 feet 6 inches, but the two end arches, which have a radius of 9 feet 6 inches, are brought down, so that the thrust of each row of arches is carried below the ground-line.

The vaulting is built with a radius of 11 feet 6 inches, but the ends of the covering arches are brought down with a curve of 12 feet 6 inches radius, till they rest on the correspondingly curved bays of the concrete end walls already described. The two exterior arches, being brought down at each end in a similar manner, form the rounded corners of the reservoir.

On the completion of the brick work, the 2-feet space between the top of the concrete wall and the surface of the soil should be filled with concrete backing, which should be carried up to the height of 6 feet above the ground-line. The earthwork of the embankment should now be proceeded with, and the floor and internal faces of the side arches rendered with Portland cement, to make the structure watertight.

By the above arrangement the thrust of the roof is carried down to an abutment, resting against undisturbed ground. The pressure of the water is not only supported by the same abutment, but it is also counterbalanced by the pressure of the made-earth forming the embankment which rests on the exterior arches of the reservoir, in addition to the pressure of the earth, which would have to resist the internal pressure, if the walls were vertical.

Where favourable conditions of site do not exist, some modification of the above plan will be necessary, such for instance, as the use of puddle, should any settlement of the

foundations be apprehended which might cause cracks in the structure.*

Cross sections and plans of other compensating or service reservoirs are also illustrated on the accompanying plates.

Proper position for settling and other reservoirs.—The best position for settling tanks, filters and reservoirs requires notice; as a rule, they should be as near the population to be supplied as possible; one reason is that the conduit between the source of supply and the reservoir requires to be of such capacity as will carry only the average hourly supply, whereas all pipes between the service reservoir and the town must be of a size sufficient to discharge the maximum or double the average hourly demand. This position cannot always be maintained, owing to a certain head on the pipes through the town being necessary and these works may require to be placed near the source or at some intermediate position between it and the town. It may, in some cases, be economical to place the settling tanks and filter beds near the source of supply and the service reservoir at an intermediate point. A study of the relative levels of the source of supply, of the town area, and of the intermediate ground will determine what the most economical arrangement will be. No rule can be laid down on the matter. The filters should be as near the site of the sand supply as possible.

To prevent the service or other reserviors being filled above a fixed level, they should be furnished with self-closing valves or overflow pipes or both; the former are desirable when an economical use of water is a necessity. To maintain a constant level of water over filter beds similar arrangements are desirable. An overflow pipe is generally connected to the scour pipe at a point beyond the valve on the latter so that the water can always find its escape. Each of these appliances are figured in the plates illustrating service reservoirs and filter beds.

PUMPING MACHINERY.

Location of pumps.—When pumping works form a portion of a water-supply system, there are various positions in which they may be located. The pumps may be placed close to the source of supply and may discharge directly on to the filter beds at an average rate during pumping hours, so that the whole supply may be delivered in 8, 12 or 24 hours as arranged, and in this case the filter beds must have sufficient

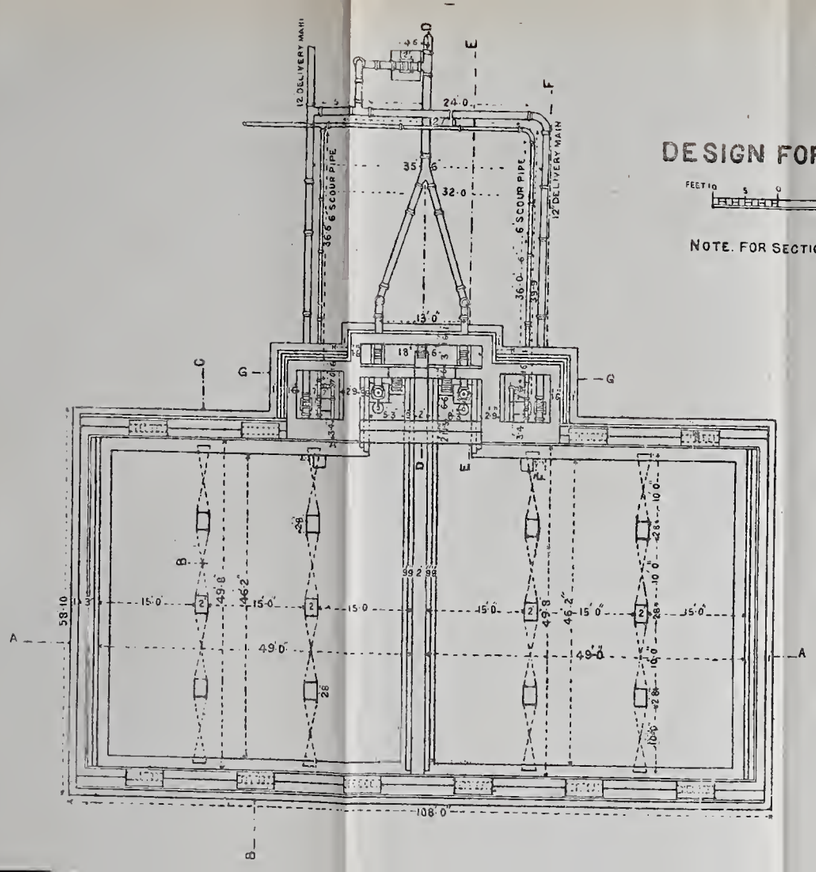
* Proceedings of Inst. C.E., vol. lxxiii.

DESIGN FOR A SERVICE RESERVOIR.

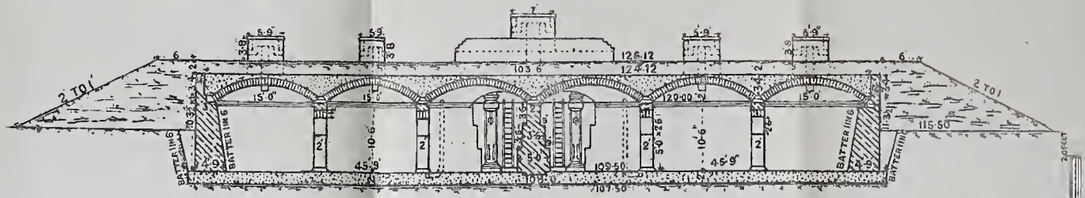
SCALE

FEET 10 5 0 10 20 30 40 50 FEET

NOTE. FOR SECTIONS ON LINES D D, E E, G G, AND H H, VIDE SUCCEEDING PLATE.



SECTION ON LINE A.A



REFERENCE

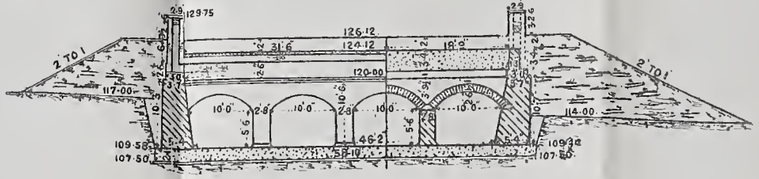
RUBBLE STONE IN CHUNAM ...

BRICKWORK IN MASONRY ...

CUT STONE ...

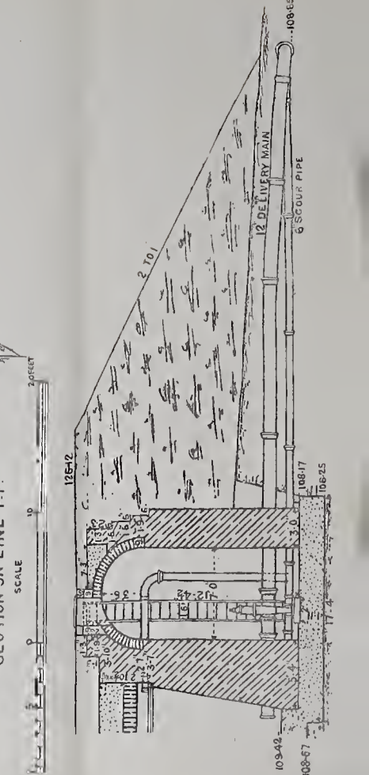
CONCRETE ...

SECTION ON LINE B.B.G.



SECTION ON LINE F.F.

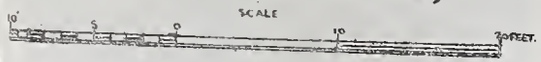
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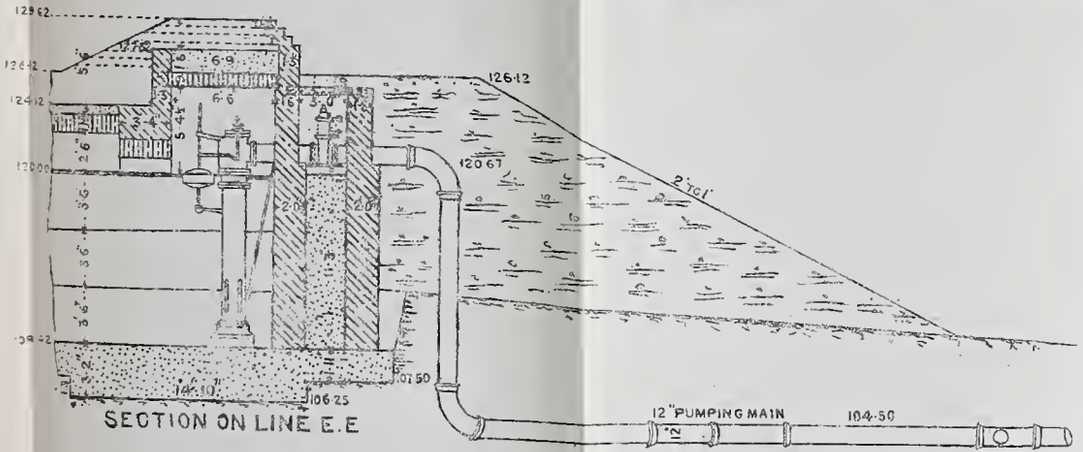
SECTIONS OF SERVICE RESERVOIR

(VIDE PLAN IN PRECEEDING PLATE.)

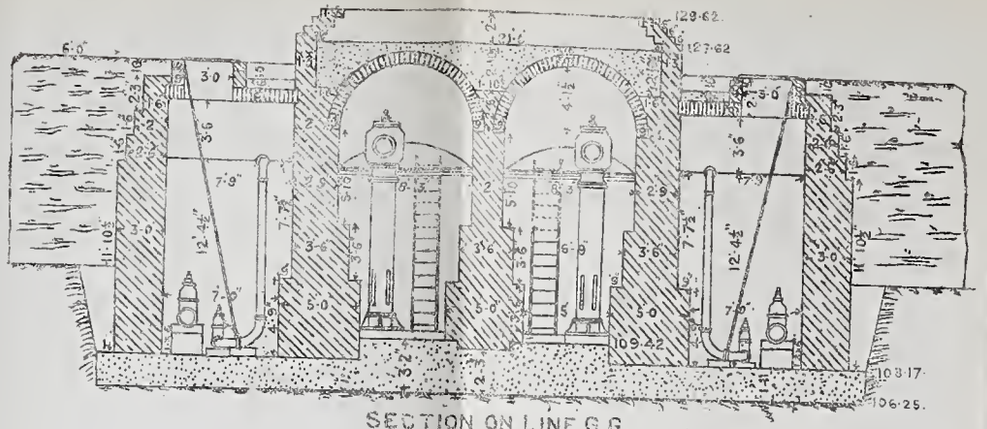
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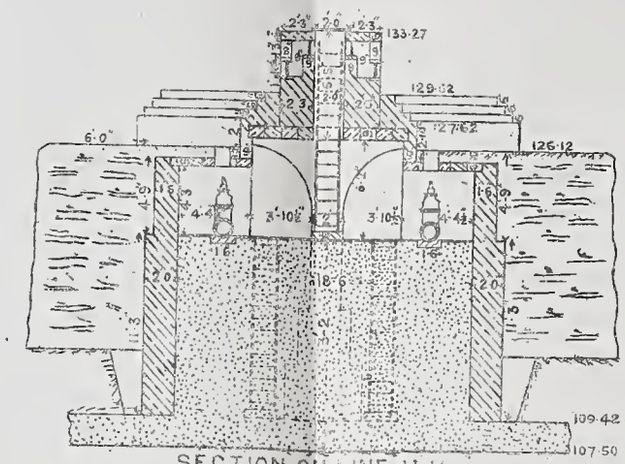
SECTION ON LINE D.D.



SECTION ON LINE E.E

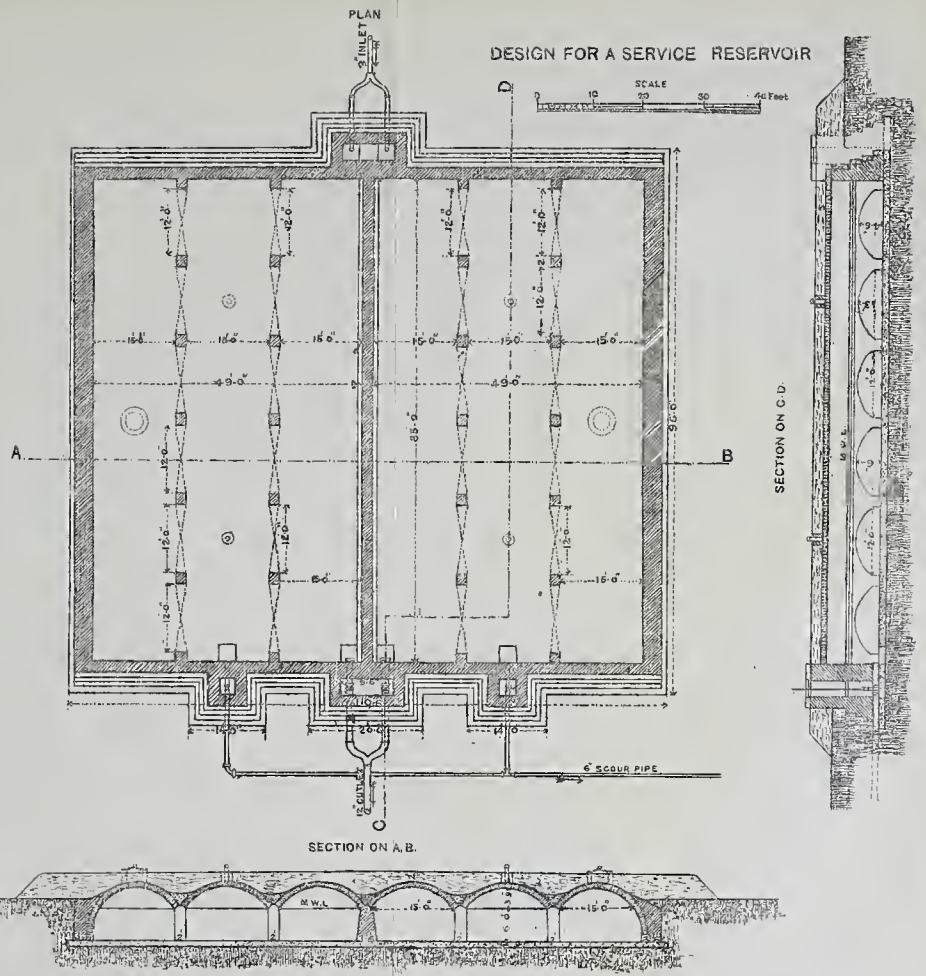


SECTION ON LINE G.G.



SECTION ON LINE H.H

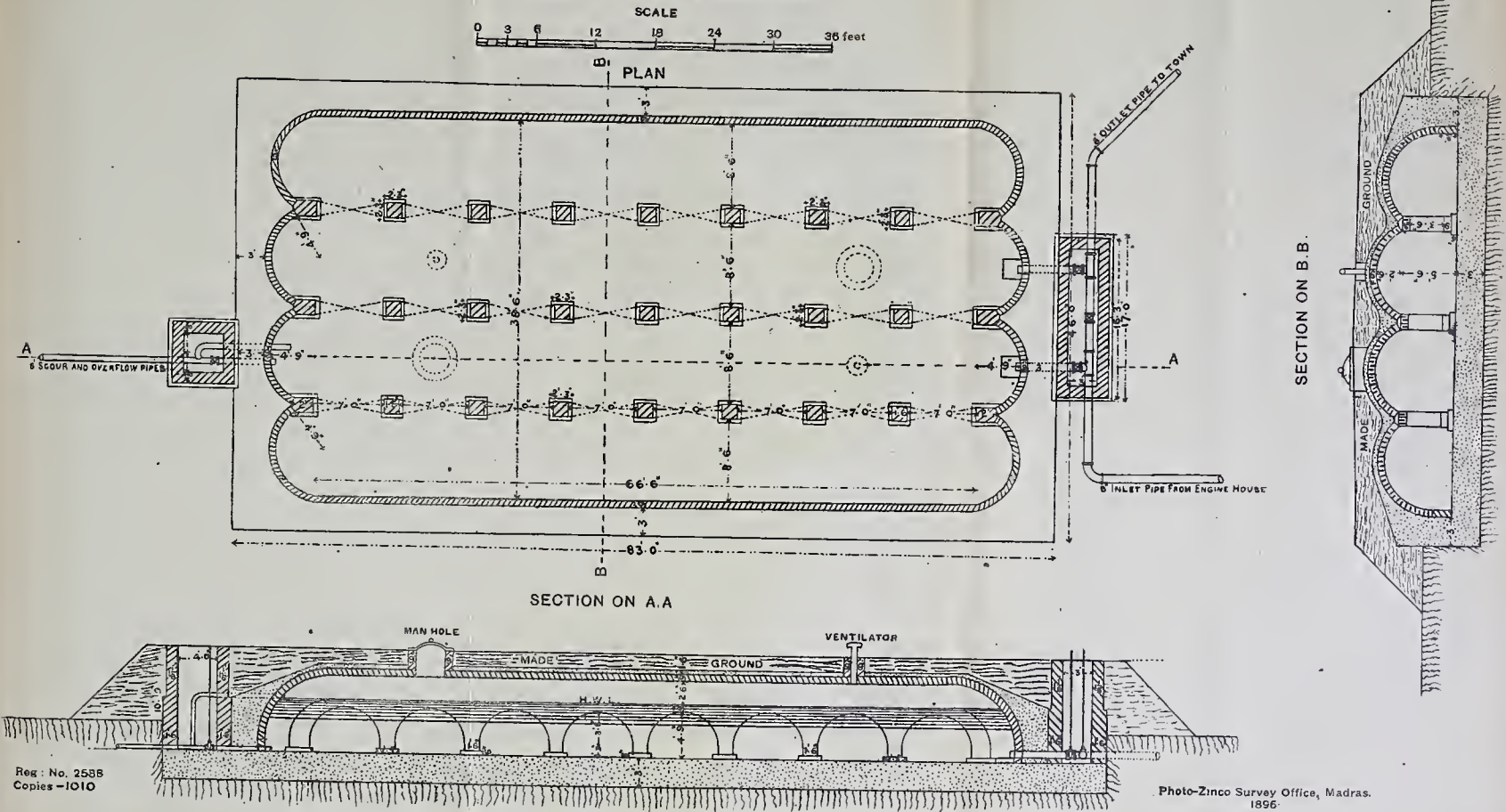
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DESIGN FOR A RESERVOIR

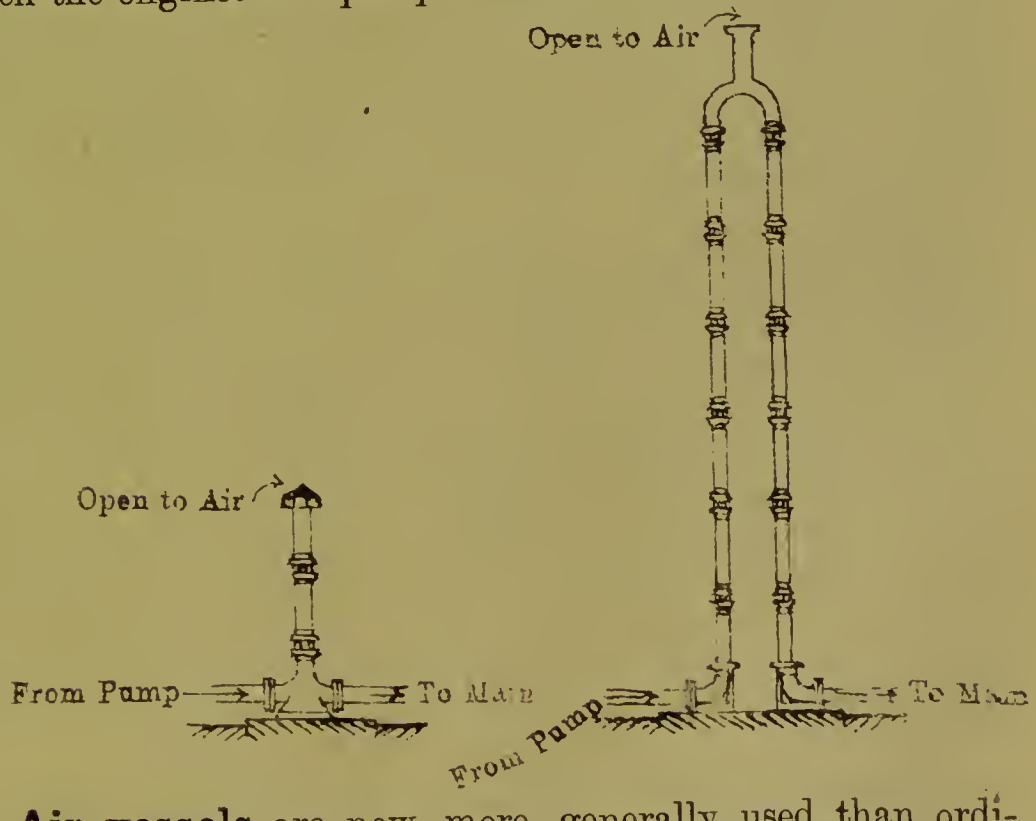


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1896

area to filter the whole supply in the selected period, and the size of the service reservoir must be determined accordingly. Again, the water may be drawn from a compensating well or tank outside the filters and then pumped into a service reservoir, it is not a practicable arrangement to draw directly from the filters; or the pumps may be placed so as to draw water from the service reservoir and pump directly into the mains; in this latter case, the machinery must be capable of pumping the maximum demand during a portion of the 24 hours.

Stand pipes.—When pumping is direct into the mains, it is often the practice to place an ordinary stand pipe between the pumps and the mains; where no high ground is available on which to place a service reservoir, a good plan is to provide a water tower; such water towers may be called tank stand pipes and are of great value as a substitute for a service reservoir at a suitable elevation over the level of the town area. These tank stand pipes should have a capacity of one day's supply. An ordinary stand pipe may be either single or double legged. With engines and pumps of the latest pattern, an ordinary single legged stand pipe is not of much use. A double stand pipe necessitates lifting the water always to the same height, whether the full pressure is required or not, but this plan ensures a steady pressure against which the engines and pumps work.



Air vessels are now more generally used than ordinary stand pipes; these with some classes of pumping engines

are of large capacity, with others such as the Worthington pumps, comparatively small.

Classification of other machines than steam pumps.—There are, of course, many other machines than steam pumps by which water may be raised, and where the population is small, one of the following may be adopted:—

(1) Ordinary picottahs.
(2) Chain pumps, norias or Persian wheels.
(3) Single, double or triple acting bucket or plunger pumps.
(4) Rotary pumps.
(5) Pumps driven by wind mills.
(6) Hydraulic rams.

The ordinary picottah, it is unnecessary to do more than refer to; as a pump, it has an extremely high efficiency.

Chain pumps consist of an endless revolving chain carrying a series of discs usually of iron. They descend into the water, and on their ascent pass through a tube carrying with them a considerable quantity of water; they have no valves, they are not easily disarranged, and can be readily repaired if broken; they can be arranged for any depth; wrought-iron pipes should be used for the tube.

The noria is one of the most simple forms of water lift and extensively used in India. It consists of a series of buckets fastened to an endless chain wound round a drum by means of gearing and is worked by hand, bullock or horse power. When bullocks are used, it is important that the gearing be speeded to suit them as they walk much more slowly than a horse.

Vertical barrel pumps of various forms and combinations are much in use. They are worked by rods actuated by suitable gearing and can be driven by hand, steam or horse power. The pumps, especially if placed low down in a well where they may be covered by water, should be made of or lined with gun metal. For deep wells three barrelled pumps are to be preferred to single or double as the flow is more continuous. The pumps should be placed as near the water as possible and when long rods for actuating the pumps are required they should be fixed and kept in a vertical line by rollers. An air vessel should be fixed to the rising main and the pump provided with a strainer and foot valve; a reflux valve on a rising main is desirable.

Rotary pumps.—The rotary pump is not actuated on the same principle as centrifugal pumps, hereafter described,

though apparently so. They are in reality revolving piston pumps, and have the advantage of not changing the direction of the flow of the water pumped at each stroke. They can be run at a high speed. One of the best forms of rotary pump consists in its interior of what may be termed a pair of very coarse toothed wheels geared into each other. These fit against the outer casing of the pump, and, as they revolve past the water inlet, produce a partial vacuum which is filled with water, and as the teeth revolve this water is swept before them into the discharge pipe.

Pumps driven by wind-mills can be used with advantage where the quantity of water to be lifted is moderate and where steam power would be expensive. A double acting force pump is best in connection with a wind-mill; but a common lift pump can be used. The pump should be of very ample size in water-way and passages. After first outlay the cost of maintenance of a wind-mill pump is very low. The wind-mill should be a self-regulating sectional mill in preference to a solid wheel mill; it is more even in speed and in storms can be arranged to coil itself automatically and cease working, whereas a solid wheel mill might be blown away altogether. The speed of the mill can be regulated by means of a governor and, by means of a tail sail, the mill can be made to always head the wind automatically.

Hydraulic rams.—The hydraulic ram may be used, where there is sufficient fall, for raising by simple means a moderate amount of water. The principle in which it works is that a larger volume of water with a certain fall will, under certain conditions, lift a smaller volume, to a higher level than its own. In estimating the amount of water that can be raised and discharged, one-seventh of the amount used can be discharged to a height equal to five times the fall, one-fourteenth part ten times as high, and so on; the following table is useful:—

Percentage of water which will be delivered by a hydraulic ram under various heads and to various elevations.

Working head.	Elevation of discharge above delivery valve at ram.					
	15	18	21	30	50	60
2	·0724	·0533	·0402	·0181	·0063	...
5	·2614	·2068	·1686	·1020	·0441	·0307
10	·6040	·4877	·4058	·2614	·1327	·1020
15	·9600	·7809	·6543	·4303	·2285	·1800
20	...	...	·9086	·6040	·3282	·2614

High or low falls may be used for rams (18 inches to 10 feet), but more than 10 feet head is not recommended, as the wear and tear on the ram is excessive. If any considerable quantity of water is required, say 1,500 gallons per hour a fall of 8 to 10 feet is suitable, and in such cases two rams working into one delivery pipe should be used in place of one. Hydraulic rams should be simply and strongly designed; all valves should be of gun metal and all joints faced. The length of the supply pipe should be as short as possible. The largest quantity of water is delivered by a ram, when the working head is great and the delivery head low.

Steam pumping machinery.—The appliances which have been described may be utilized in connection with water-supplies to villages or very small towns; where larger populations are concerned, steam machinery must be adopted if water has to be raised by mechanical means. With steam pumping machinery especially with larger water-supply systems any break-down would mean entire loss of supply to the town, and it is therefore of the greatest importance that the machinery should be perfectly reliable.

High-class machinery economical.—The cost of fuel is an expensive item in working machinery; in India it is especially so. Therefore all machinery used in Indian water-supplies should be of the highest class, that is, its efficiency in the sense of raising the greatest possible quantity of water for the least possible amount of fuel consumed, should be the first consideration. Some knowledge of the principles of pumping machinery is therefore very desirable, though the question of details may be left to the makers. In this view it is well not to issue too elaborate specifications, but to confine these to a description of the class of machinery required for the amount of work to be done, the position it is to occupy and the conditions under which it is to work.

The waste of public money by purchasing cheap machinery, even in England is enormous. Such machinery does not work economically and deteriorates rapidly, requiring large expenditure in fuel and repairs; in India, as already pointed out, inferior machinery would show still greater waste.

Reserve of power necessary.—It is desirable at all pumping stations for water-supply to have a reserve of power in the case of a breakdown, and a desirable plan is to have three engines, each capable of doing one-half the work. In very large works a greater sub-division should be adopted. In small installations where such a division would bring down

the power of any engine below ten horse-power, it is advisable to have two engines only, each capable of doing the whole work. Economy in working, in the case of larger installations, is also thus secured if pumping is being done into the main direct, because two engines will be working during the hours of maximum demand, and only one will be required during other periods; it is more economical to work an engine up to its full power than to any proportion of its power.

Duration of pumping.—When pumping is into a reservoir, it is not desirable for the work to go on through the 24 hours; this would require three sets of men and eight, twelve or sixteen hours' work only is advisable.

'Duty' of machinery.—In calling for tenders for engines, tenderers ought always to be required to state what the 'duty' of the engine tendered for, will amount to. The *duty* is the effective work of a pumping engine, and is expressed by the ratio of the product in foot pounds of the weight of water lifted into the height lifted, to one cwt. of coal burned. This is considering the work of the boiler and the work of the engine as the work of one machine, and is not strictly correct; but it is probably sufficiently so when considering tenders. Tenderers however sometimes prefer to give the number of pounds of steam which will be evaporated for each pound of fuel used (this refers to the boiler only), or the amount of steam required per indicated horse-power per hour.

The following is a comparative table showing the fuel expenses for pumping compared on a duty basis (coal at Rs. 20 per ton):—

Duty in million of foot pounds.	Number of million of gallons daily one hundred feet high.					
	1	2	4	6	8	10
	Cost of fuel per annum.					
	Rs.	Rs.	Rs.	Rs.	Rs.	Rs.
100	3,259	6,518	13,036	19,554	26,072	32,590
90	3,621	7,242	14,484	21,726	28,968	36,210
80	4,074	8,148	16,296	24,444	32,592	40,740
70	4,656	9,312	18,624	27,936	37,248	46,560
60	5,432	10,864	21,728	32,592	43,456	54,320
50	6,518	13,036	26,072	39,108	52,144	65,180
40	8,147	16,294	32,588	48,882	65,176	81,470
30	10,863	21,726	43,452	65,178	86,904	1,08,630
20	16,295	32,590	65,180	97,770	1,30,360	1,62,950

Note.—For any other lift than 100 feet take the cost in proportion.

From the above table the following comparison for example may be made; if two millions gallons are to be pumped daily with a 100 million duty engine, it would cost Rs. 6,518 per annum; this with a 70 millions duty engine would cost Rs. 9,312 per annum. If these sums be capitalized, they represent the financial values of the engine as regards fuel.

There are, however, in permanent and large installations, other factors to take into account such as the cost of buildings, foundations, stand pipes.

Let R be the cost in rupees of the pumping station with engines and appurtenances and D the duty in millions, then the most economic engine is when $\frac{R}{D}$ is least, or otherwise let $\%$ be the rate of interest at which the cost is capitalized, then the most economic engine will be that with the least product of $\frac{R}{\%} \times \frac{1}{D} = \frac{1}{\%} \times \frac{R.}{D}$

The following is a comparative table of values of pumping engines of various prime costs and duties on the fuel basis:—

Cost = R.	Duty = D.	$\frac{R}{D}$	Ratio.
RS.	MILLIONS.		
1,00,000 ...	100	1,000	1·00
80,000 ...	75	1,066	1·066
70,000 ...	60	1,166	1·166
50,000 ...	40	1,150	1·150
30,000 ...	20	1,500	1·500

From the above table it will be ascertained that the Rs. 30,000 engine will be the most costly, and cost 50 per cent. more per annum than the engine costing Rs. 1,00,000. It may be however that the Rs. 80,000 engine is of less complicated design, and requires less skilled attendance, and the difference in annual cost being only 6 per cent.; its adoption for these reasons should be considered.

Fuel used in relation to horse-power.—Though the measure of 'duty' is suitable for estimating the work done by pumping engines, it is not convenient for other purposes and it has become the practice to estimate the performance of an engine by ascertaining the number of pounds of coal burnt per hour for each horse-power at which an engine is working. It is a common performance with large * steam engines to burn 4 lb. of coal per indicated horse-power per hour, and the 'duty' of such an engine would be deduced as follows:—Let the duty be

* Above 50 horse-power.

estimated by burning 112 lb. coal, $60 \times 33{,}000 =$ foot lbs. per horse-power per hour. Then $\frac{112 \times 60 \times 33{,}000}{4} = 55{,}440{,}000 =$ duty of engine.

Consumption of fuel.—There has been great progress made in economy of fuel by successive improvements in steam engines. The average consumption in 1863 for the best marine engines was $4\frac{1}{4}$ lb. per indicated horse-power per hour, in 1872 it was 2·11 lb. But even $2\frac{1}{2}$ lb. of coal per horse-power per hour in pumping engines is a very economical performance especially if the load against the engine is at all variable.

The following table shows the duties corresponding to various amounts of coal per horse-power per hour :—

Pounds of coal per horse power per hour.	Duty, millions of foot pounds.
6·0	36·94
5·0	44·35
4·0	55·44
3·5	63·36
3·0	73·92
2·5	88·70
2·0	110·88

Consumption under steady loads.—From the most favourable results which can be regarded as not exceptional, it appears that, in the best trials of engines of 50 horse-power and over with constant and full load, the expenditure in coal or wood (heat value of wood to coal as 1 to 4) and steam is about as follows :—

——	* Per indicated horse-power per hour.			* Per effective horse-power per hour.		
	Coal.	Wood.	Steam.	Coal.	Wood.	Steam.
	LB.	LB.	LB.	LB.	LB.	LB.
Non-condensing engines	2·20	8·80	20·00	2·44	9·76	22·0
Condensing engines.	1·50	6·00	13·50	1·75†	7·00	15·8

* *See* page 324 *seq.*

† *Note.*—A condensing engine of 8 to 10 horse-power will require as much as 9 lb. of good coal.

Consumption with varying loads.—It is much more difficult to determine the quantity of coal used by engines in daily and variable work, but the following table shows the variation of steam consumption with full, half, quarter and one-eighth loads :—

Indicated horse-power and loads.	Steam consumption in pounds per hour.		
	Non-condensing.		Condensing.
	Compound.	Triple.	Triple.
Full (100)	21·5	18·2	14·9
Half (50)	26·7	22·7	16·0
Quarter (25)	37·2	31·7	18·2
One-eighth (12½)	58·2	49·8	22·7

Classification of machinery used for water-supply.—The machinery most commonly used for water-supply includes

Beam engines (rotative).
Horizontal and vertical rotative engines.
Direct acting steam pumps horizontal or vertical.

The engines may be condensing, or non-condensing, high pressure compound, triple or quadruple expansion. The most economical engine with reference to the cost of fuel alone is a condensing engine with triple or quadruple expansion.

Beam engines.—The ease and smoothness of action of a beam engine render it most enduring, and where an engine is required for unchanging and moderate work at a moderate speed such as in water pumping to a town, many engineers still prefer the beam engine notwithstanding its excessive cost as compared with other types.

With beam engines the pumps work directly from the beam; with horizontal engines either by the piston rod extended or by a rocking shaft, when the pumps have to be below floor level, or by a belt if pumps of the centrifugal class are used.

Horizontal engines.—The horizontal class of engine is undoubtedly the cheapest; it lies low and steadily on a level foundation easily constructed; it requires less head room, but more floor space in comparison to a beam engine.

The direct acting steam pump is the most modern type of pumping machinery. In this class of machine the pump and steam cylinder are placed close together in a line on one bed plate or if vertical below one another, the piston rod from the cylinder being continued into the pump. Duplex steam pumps have two steam pumps placed side by side, both controlled through the medium of flat side valves as used in a steam engine. These pumps have no dead centres, and as each piston is made to pause at the end of its stroke, and the plunger of one pump commences its stroke before the other finishes, ample time is allowed for the water valves to properly seat themselves. Any dead point is avoided by mechanically actuating each steam valve from the piston rod of the opposite cylinder, consequently the pumps can start from any point of the stroke and deliver a steady flow of water. The engines actuating these pumps are now made triple expansion and condensing, so that great economy in fuel is secured.

Classification of pumps.—The pumps used in connection with beam and rotative engines for water-supplies may be lift, force, or pressure pumps, all of which have a bucket or plunger with a reciprocating motion, or with the latter class of engine, centrifugal pumps.

Lift pumps.—The lift pump is that generally employed for raising water from wells; it has as a feature a hollow bucket through which the water, after it has been forced up by the atmosphere during the forward state, passes as the bucket returns. Sometimes a forcing plunger is combined with a lifting bucket.

Force pumps.—Force pumps have a solid bucket or plunger or piston which works in a barrel furnished with inlet and outlet valves, the water flowing through the inlet valve into the barrel as the plunger leaves a vacuum behind it. These pumps may be double or single acting. Bucket and plunger pumps are those in which a forcing plunger is fixed above the bucket on the same rod, so that while there is only a single action suction there is a double forcing or delivery.

Centrifugal pumps.—This is a class of pump differing much from any of those just described. Pumping is performed by a rotating disc with radiating blades (bent to an effective curve) working inside a casing at a high speed. The high speed causes a vacuum and the water follows by pressure of the atmosphere to be once more displaced and thus passed into the delivery pipes. These pumps are suitable where large quantities of water have to be dealt with in

a short time and where the lift is comparatively low; they can be made to lift and force a total of 80 or 100* feet or more; a lift of 20 feet is probably that below which they are most economical. The manufacture of such pumps is in few hands as they demand the application of principles arrived at only after long, steady and careful experiment. These pumps may be driven by any rotative engine or through gearing or by an engine whose crank shaft is an extension of the pump spindle. Well-made centrifugal pumps under effective conditions give an efficiency which is often as high as seventy per cent. The quantity of water delivered by centrifugal pumps of various sizes and various lifts will be found in a table in the appendix.

Pulsometer pumps.—Another class of pump is the pulsometer class. This class consists of two chambers, steam being admitted to one of them forces up the water within it. The steam becoming condensed forms a vacuum into which the water from below ascends, while the upward forcing process is being performed in the second chamber and thus by a succession of pulsations pumping is continuous. These pumps are useful for temporary purposes, as they can be slung by a chain down a well and they will pump very thick and impure liquids. They cannot lift more than 25 feet, but, with high steam pressure, can force a considerable height. They however consume a large quantity of fuel in proportion to the work done.

Boilers.—The boilers used with stationary engines may be Cornish, Lancashire or multitubular boilers. The two former are cylindrical boilers usually with flat ends; the Cornish is furnished with one flue and the Lancashire with two. The boilers are covered with brickwork in which flues are placed, so that the flames and heat passing out of the tubes are taken along the outside of the boiler and thence to the chimney.

Multitubular boilers are either horizontal or vertical; in such boilers there are, instead of one or two tubes, many of small diameter, and steam can be produced very rapidly. A great reduction in size is, therefore, possible and no brickwork or setting is required. The multitubular boiler is often of the locomotive shape for which it was first designed. Whether Cornish or Lancashire or multitubular boilers are best for stationary engines is a debatable question; the sizes

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* Messrs. J. & H. Gwynne state that they are now making pumps (series centrifugal) which lift economically over 300 feet.

of the latter are limited; they are also more expensive, but the tendency is towards a very high pressure steam and quick speed engines, and it is sometimes difficult with a Cornish boiler unless it be made of excessive size to maintain a sufficient supply of steam. These opposing conditions have led to the construction of a hybrid class of Cornish boiler furnished with cross tubes.

Tubular boilers.—A boiler composed entirely of tubes is a new class of boiler finding much favour. The tubes are suspended in frames and lie at an angle from the horizontal; these tubes are over the fire and through them the water circulates and the steam is passed finally to a horizontal tube of larger size whence the steam is taken to the engine. These boilers heat water very quickly, they are very portable, easily taken to pieces and free from dangerous explosion, since the bursting of one tube would cause inconvenience only and not disaster. The chief objection to them is that their numerous joints allow more leakage than in other forms.

Selecting and ordering machinery.—The following points require consideration by those who are selecting or ordering steam machinery, boilers and pumps. In permanent installations (1) the floor space available and whether horizontal or vertical engines can be used; (2) the weight of the engine or its largest part with reference to landing and transport facilities; (3) whether great simplicity of design is desirable or whether for more complex machinery skilled workmen would be available and greater economy in fuel possible. When the installation is not permanent, perfect portability of the engine and boiler and pump is a necessity.

When these points have been considered, the following information should be given when calling for tenders:—

(1) The purpose for which the engine is required and whether for permanent or temporary use.

(2) The power required or work to be done or such information as will allow these to be calculated. In giving the height to which water has to be raised above the engine floor level, all losses of head due to friction in mains, bends, &c., must be considered and the total lift including all these and other losses except those due to the engines and pumps themselves must be given.

(3) The class of engine and boiler found most suited to the country.

(4) The space available for engine and boiler, its level as compared with the minimum level of the water-supply, and

the maximum height to which the water has to be raised. A plan and section of the building in which the engine is to be erected should be furnished with a description thereof.

(5) The kind of fuel available, its quality as compared with some standard English coal (*see* appendix).

(6) The water available for boiler and condenser, and the height or pressure at which it will be delivered.

(7) The class of workmen available for erecting the machinery ; import duties, railway and other charges between port of landing and point of erection.

(8) The facilities available for making repairs.

Engineers usually are able to specify some particular type of engine, and whether it is to be horizontal or vertical, expansive, condensing or non-condensing, &c., and it is usual, as before stated, to require that the boilers shall give out at certain duty, or that the engine shall develop so many horse-power for each pound of fuel burnt per hour as a maximum.

Horse-power.—The word horse-power is very often qualified by the words 'Nominal,' 'Indicated,' 'Effective,' &c. The standard horse-power of Watt is 33,000 foot lb. or 33,000 lb. lifted one foot in one minute. Watt based his engine power on a pressure of 7 lb. per square inch and a piston speed of 160 feet a minute, but with increased pressures and greater velocities engines made of similar dimensions give out much greater power, so that 2 to 1 and even up to 6 to 1 are proportions between actual and nominal. The word 'Nominal' is still used in mercantile transactions, and for non-condensing engines an 8-inch cylinder or a cylinder of 64 circular inches will be provided for a 6 horse-power engine, a 10-inch for a 10 horse-power and a 12-inch for a 14 horse-power.

Indicated horse-power.—The 'Indicated' horse-power of an engine is found by an instrument called an 'Indicator' which gives a diagram of the steam pressure in the cylinder at each point of the stroke. By this instrument the mean pressure is calculated and the mean pressure exerted multiplied by the area of the cylinder into the distance in feet travelled gives the 'Indicated' horse-power.

Effective horse-power.—From the indicated horse-power has to be deducted the losses due to the friction in the engine itself and pumps in connection with it, and the balance is called the 'Effective' horse-power. These losses in an engine itself amount to from one-half to one-quarter of the

indicated horse-power. The effective horse-power is the real gauge of the value of an engine.

For an installation including pumps, &c., the allowances hereafter given are advisable when machinery is ordered on the basis of horse-power.

Calculation of horse-power.—If it is necessary to specify what horse-power an engine must develop, a calculation for the indicated horse-power required must be made on a basis somewhat as follows:—Find the total lift; this equals the distance from lowest level of the water to the level of the pipe *plus* a height above; this height equals the head required to deliver the maximum supply of water through the main, in fact the height up to the level of the hydraulic gradient at the pumping station.* The effective horse-power required will be

$$\frac{G \times 10 \text{ lb.} \times h}{33000}$$

when G = the number of gallons lifted,
10 lb. = weight of a gallon,
h = total lift as above described.

For engines less than 12 horse-power it is well to add 50 per cent. to this power;
For engines from 12 to 20 horse-power add 33 per cent. to this power; and
For engines over that horse-power add 25 per cent. to this power;

These quantities added will give about the indicated horse-power required, and the engine should give out more than the effective horse-power as calculated by the formula.

Suction pipes.—A word or two is necessary in regard to suction pipes. Theoretically a pump can lift or rather the atmosphere will balance a column of water 34 feet high, but in practice very much less owing to imperfect vacuum. With very perfect construction and care, pumps may be made to draw 26 to 28 feet, but it is always advisable to place the pump as near the water level as possible and not more in

* If the total horse-power required is divided among two engines, so that one engine can deliver the quantity required during the hours of lesser consumption, say, one-half the maximum only, that engine will not be called on for its full power, as the hydraulic gradient will be lowered with the diminished supply, but two engines equal to twice this actual power required would be insufficient, as they have when working together to pump up to the level of the hydraulic gradient due to the maximum demand.

any case than 25 feet above it, that is, measured to the highest point of the pump barrel. The actual length of suction main is not of so much importance, but long suctions are to be avoided if possible, as they increase the amount of water to be set in motion and stopped at every stroke unless the flow is perfectly continuous. A direct acting vertical engine therefore has one great advantage over a horizontal one, because the pump can be placed at any depth below the pump floor.

The cost of steam-power in any place can be determined only by careful estimates with reference to local conditions; the cost of fuel, facilities for obtaining water, the cost of labour, &c., the type of engines and buildings are more or less varied in each particular case. Further, as already pointed out, the regularity of load on the engine materially affects the cost of working. With engines and boilers of 100 horse-power and over, the cost per horse-power does not vary much; with engines of less power, it rapidly increases as the power decreases.

The following table is from Unwin and is an estimate of cost of ordinary engines and boilers, pipes and auxiliary apparatus such as are absolutely necessary :—

Cost of Steam Plant.

Indicated horse-power	1	10	50	200
Effective horse-power	0·7	7·5	40	165
Cost per indicated horse-power in £	56	30	24	20
Cost per effective horse-power in £	80	40	30	25

To these prices, the cost of freight and transport charges must be added to obtain the price in India.

The cost in India of Worthington Triple Expansion condensing engines and pumps with all necessary boilers, steam piping and connections, waste pipes and erection, &c., is about as follows :—

Effective horse-power.	30	25	20	15	10	5	2½
	£	£	£	£	£	£	£
Cost per horse-power, horizontal	48	55	65	75	100	130	170
Cost per horse-power, vertical	51	58	70	80	110	140	180

The cost must be calculated with reference to the size of the individual engines and *not* with reference to the total horse-power thus :—

Suppose the total required is 30 horse-power and that three horizontal engines of 10 horse-power are desirable, these will cost 3 × 10 × £100, or £3,000, or two engines of 15 horse-power will cost 2 × 15 × £75, or £2,250.

Coal consumption.—The following is an estimate of the coal required for actual working, including waste due to lighting up, cooling, working auxiliary pumps, &c. :—

Indicated horse-power	1	10	20	50	200
Effective horse-power	0·7	7·5	18	40	165
Coal per indicated horse-power per hour ... ... lb.	8	6¾	4	2¾	2
Coal per effective horse-power per hour ... ... lb.	11½	9	5	3½	2¼

Labour and stores.—In England 5*s.* per effective horse-power per annum is allowed for petty stores for moderately large engines (above 10 horse-power) and for labour of driving and stroking £1–2–0 per effective horse-power for 3,000 hours, (for engines below 10 horse-power, these rates are higher).

The following are from actuals in the author's practice :—

——	Madura.	Tanjore.
Description of engines ...	Worthington triple expansion, horizontal.	Worthington triple expansion, vertical.
Number of engines	3	3
Indicated horse-power ...	20·84	20·2
Effective horse-power ...	17·28	17·57
Number of boilers	3	3
Class of boilers	Locomotive.	Babcock and Wilcox.
Cost of engines and boilers ...	£3,510	£3,788
Cost of buildings	Rs. 36,710	Rs. 35,650
Cost of engines and boilers per indicated horse-power . .	£168·42	£ 187·52
Cost of buildings per indicated horse-power	Rs. 1,761·51	Rs. 1,764·85
Cost of staff per month ...	„ 259	„ 267
Cost of fuel, stores, &c., per month	„ 258·6	„ 353·1
Cost of staff per indicated horse-power per month ...	„ 12·42	„ 13·22
Cost of staff per effective horse-power per month	„ 14·99	„ 15·19

In arranging engines for water-supply works, it is to be remembered that the work to be done by an engine must always be considered in relation to the special circumstances of each case. It does not follow that, because the lift and quantity, to be pumped per diem are the same, the engines must be of the same horse-power. For instance, the machinery in one case may be required to pump into a service reservoir from which the town is supplied and may then pump the water in 24 hours, 16 or 12 hours as decided, and it is often advisable to do this to avoid men working at night. Where the pumping is done directly into the mains, the engine must be such that at least double the average quantity required per head can be pumped or one-half the demand in six hours.

The following plates illustrate the various classes of engines and pumps spoken of :—

(1) Beam engine.

(2) Horizontal condensing engine (rotative).

(3 & 4) Direct acting triple expansion engines and pumps.

(5) Portable engine.

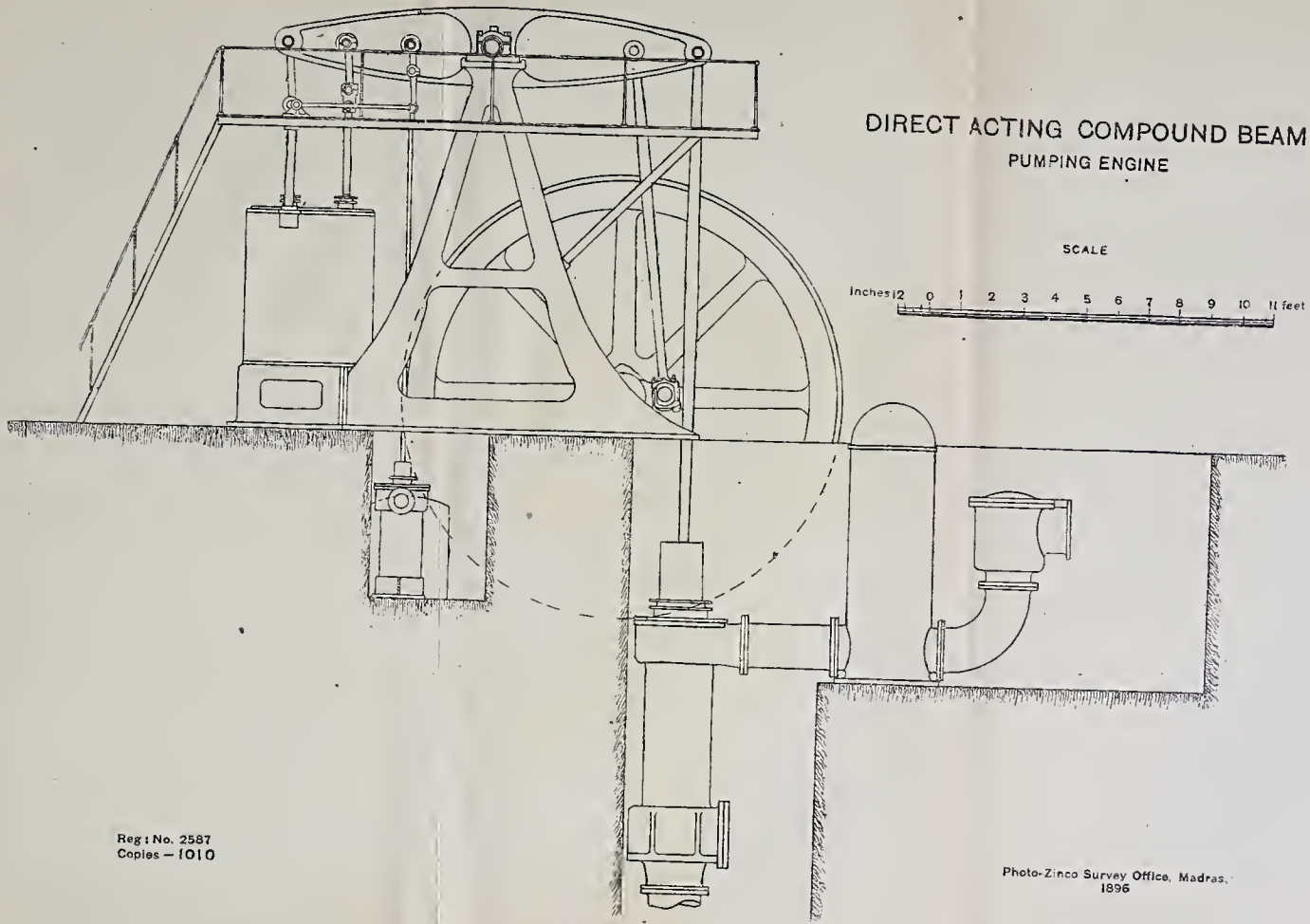
(6) Pulsometer.

DETERMINATION OF SIZES OF MAINS AND BRANCHES.

The necessity for determining and proportioning carefully the sizes of mains is not one that has, until very late years, been impressed on engineers generally. It is a troublesome problem, but it is of no less importance than the design of any other portion of a water-works system.

Systems of supply.—In England and other countries, there are two systems of supply, the constant and intermittent; in the latter system the water is delivered to the consumer between certain hours only. He is thus obliged to store it, and as storage is seldom effected under very sanitary conditions, the system is far from a desirable one. Its disadvantages in addition to the above are many. The system is one that does not find place in modern systems of supply, so that further remarks regarding it are unnecessary.

Constant system.—Under the constant system, water is available to the consumer during the whole twenty-four hours, the water for all purposes (except for water closets)



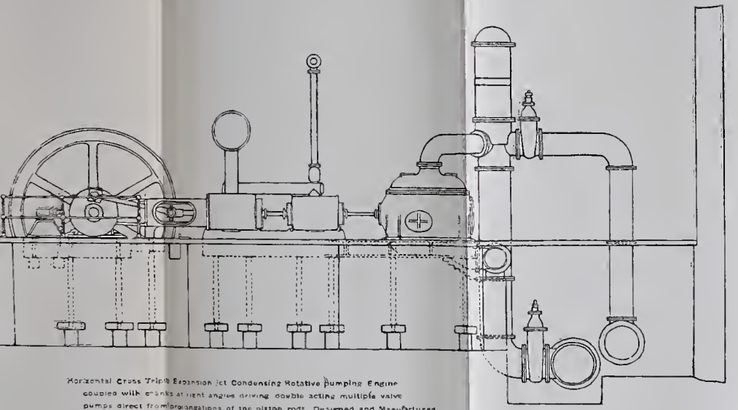
DIRECT ACTING COMPOUND BEAM
PUMPING ENGINE

SCALE

Inches 12 0 1 2 3 4 5 6 7 8 9 10 11 feet

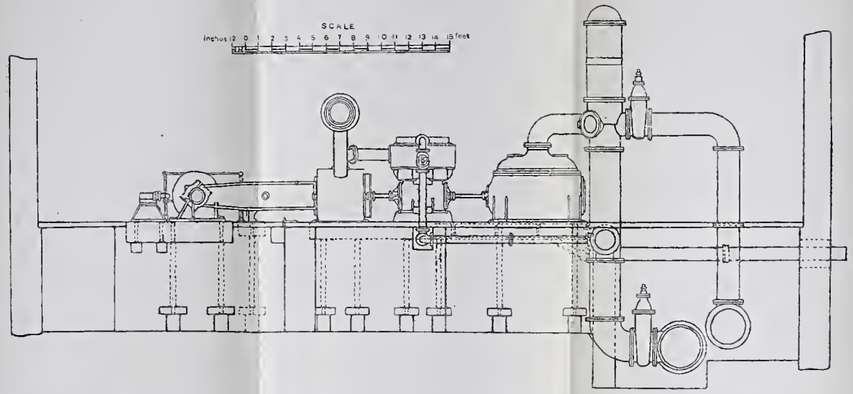
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Horizontal Cross Triple Expansion Jet Condensing Rotative Pumping Engine coupled with cranks at right angles driving double acting multiple valve pumps direct from prolongations of the piston rods. Designed and Manufactured by James Simpson and Comp.y for St. Petersburg Water works Russia. Capacity 3000 gallons per minute 220 feet head with a steam pressure of 150 lbs

No. 7598
es 1010



HORIZONTAL CROSS TRIPLE EXPANSION JET CONDENSING ROTATIVE PUMPING ENGINE.

JAMES SIMPSON AND COMPY. Ltd
ENGINE WORKS
CROSVENOR ROAD
PIMLICO.
LONDON.

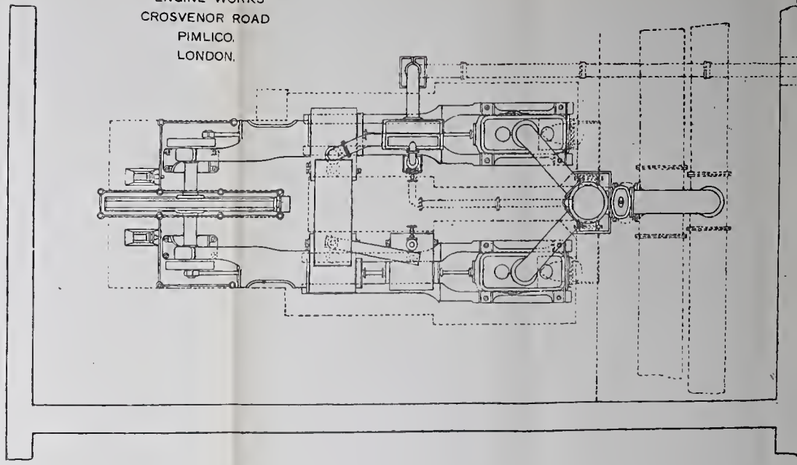
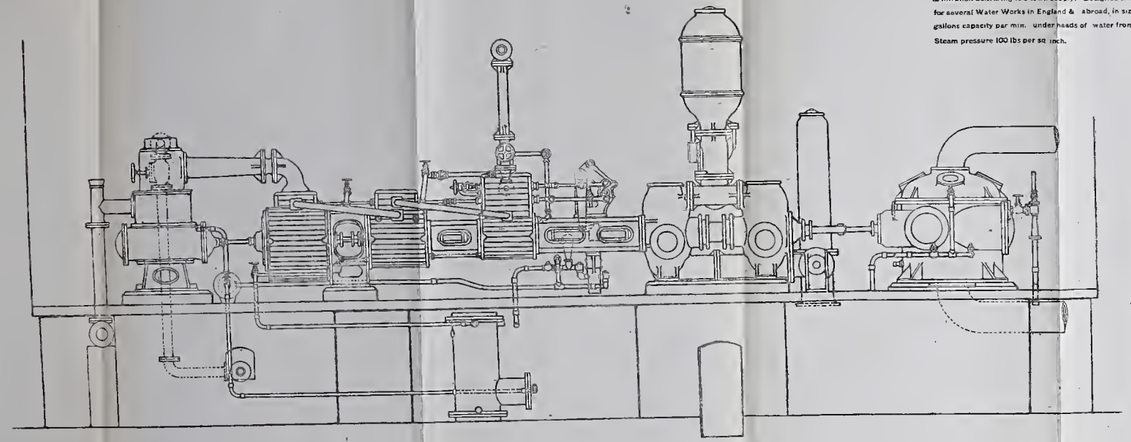
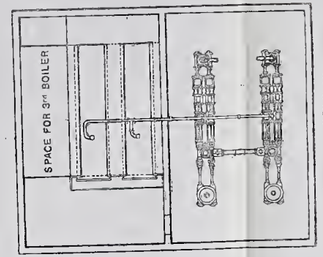


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HORIZONTAL TRIPLE EXPANSION JET CONDENSING WORTHINGTON PUMPING ENGINE

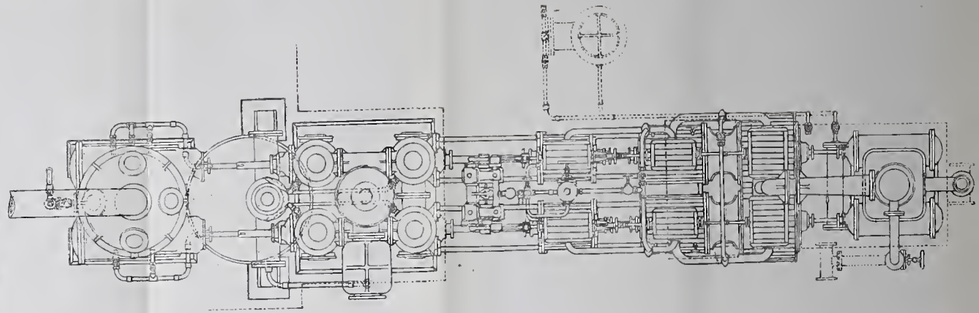
With High & Low Lift Pumps, arranged for drawing water from a river & after settling & filtration delivering to a town supply. Designed & made by Jas. Simpson & Co. Ltd. for several Water Works in England & abroad, in sizes ranging from 500 to 2,000 gallons capacity per min. under heads of water from 100 to 400 feet.
Steam pressure 100 lbs per sq inch.





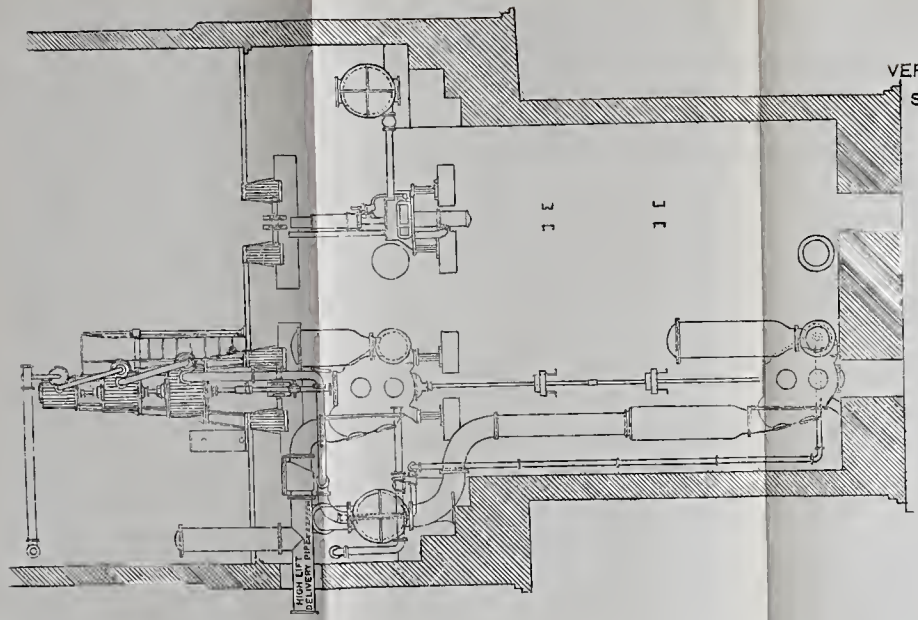


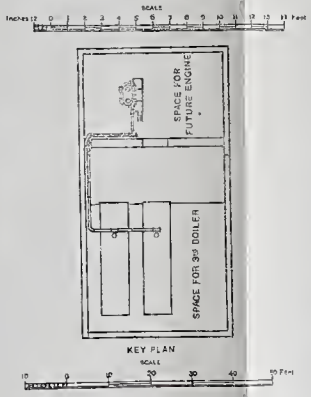


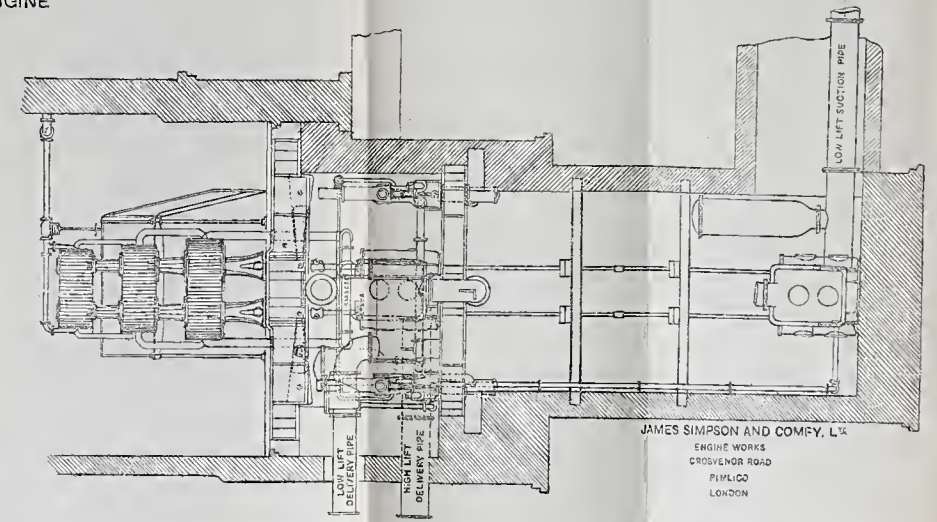


VERTICAL TRIPLE EXPANSION WORTHINGTON SURFACE CONDENSING PUMPING ENGINE

with High & Low Lift pumps, arranged for drawing water from a river & after settling & filtration, delivering the same for a town service, designed, & made for Water works in England & South America—In sizes varying in capacity from 500 to 2000 gallons per min under heads of water from 100 to 400 feet Steam pressure 100 lbs per Sq Inch





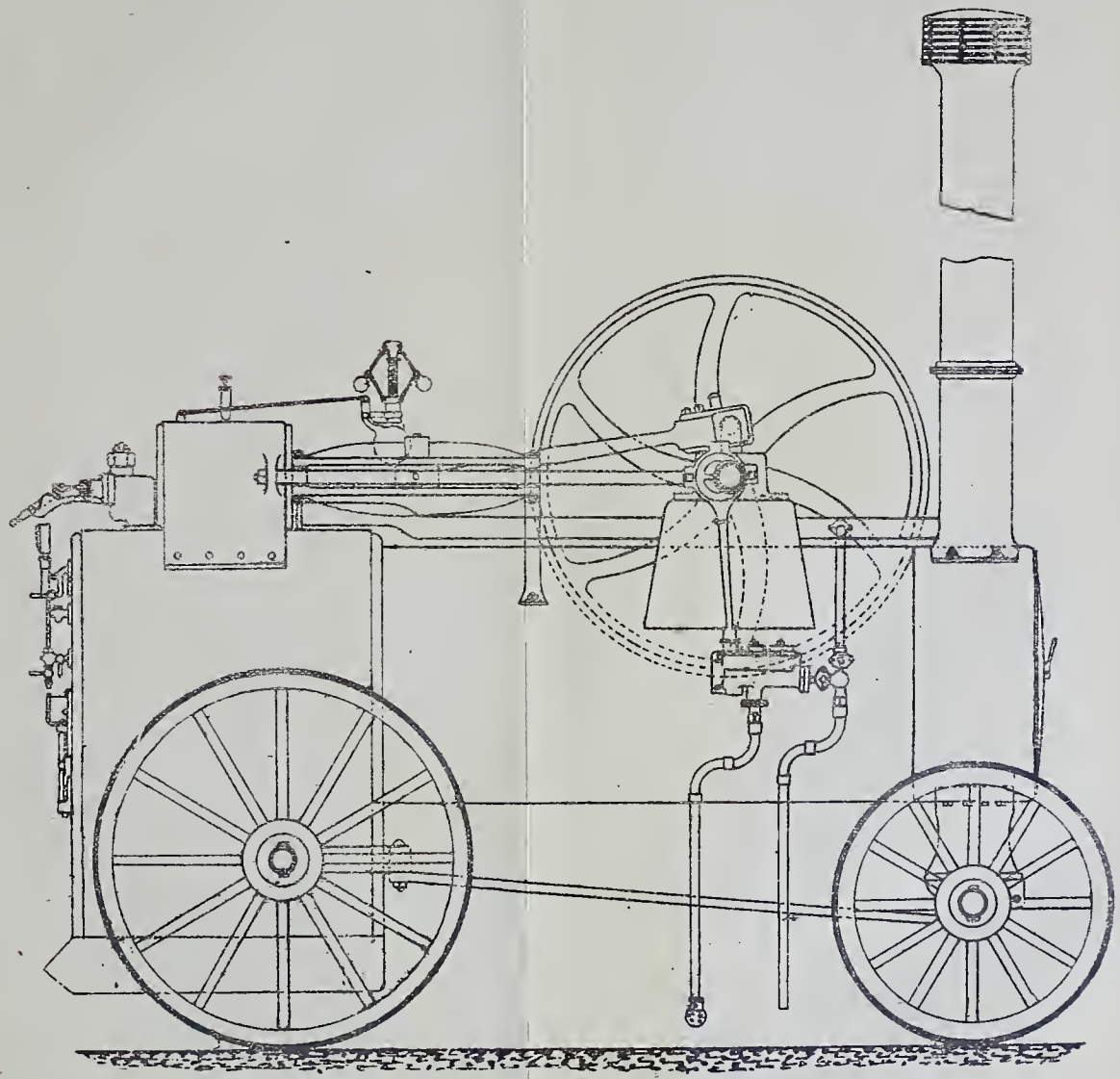


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ENGINE WORKS
CROSVENOR ROAD
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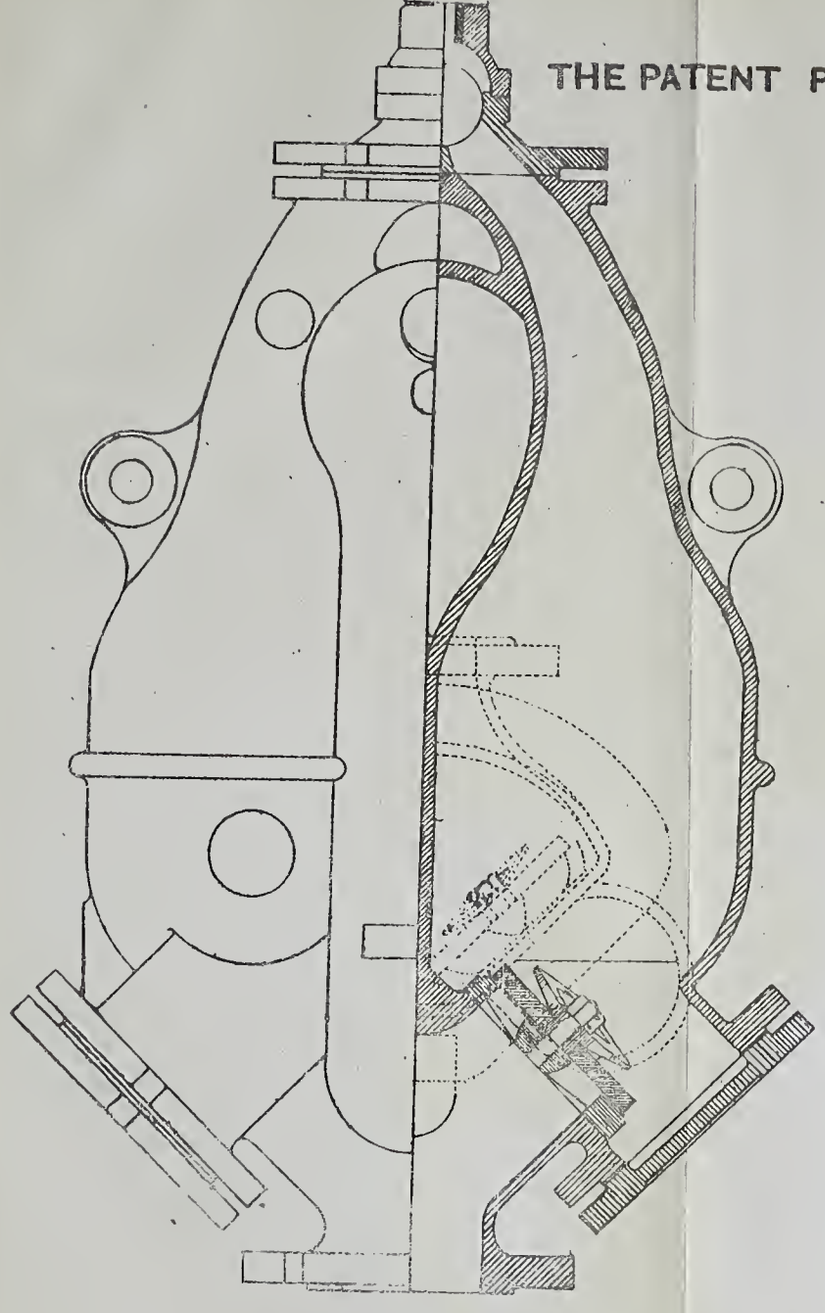
BOILER AND ENGINE (PORTABLE)

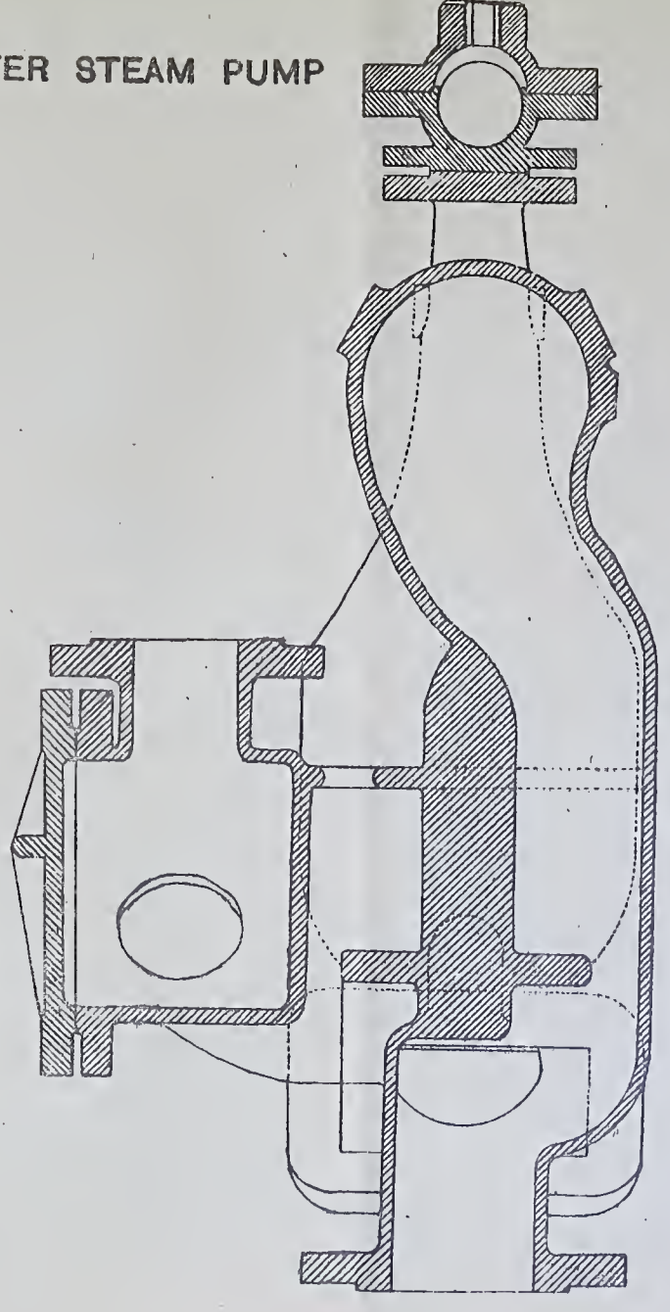


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THE PATENT PULSOMETER STEAM PUMP





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Photo-Zinco Survey Office, Madras.
1906

being drawn direct from the pipes. In India where the pumps discharge directly into the mains, the demand after 8 P.M. to 5 A.M. is sometimes too small to warrant pumping being continued during these hours, and where there is a long and large main outside the town falling towards it and holding a considerable supply of water, there is not much objection to this plan; otherwise it is better to keep the pumps working, or foul air, &c., may be drawn into the pipes.

Variation of demand.—When proportioning mains, a point to be considered is the *average* quantity of water to be carried. Whatever quantity is decided upon as the supply per head (and the total quantity should allow for an increase in population), the mains must be designed to carry a multiple of that amount determined with reference to the fact that the water is not used at an average rate throughout the day, and that usually the greater proportion of the water is used in six hours.

The following table shows the variation in the daily supply the result of an experiment at Wolverhampton :—

Time.	Percentage of gross consumption.	Time which would be occupied in delivering gross consumption.
		HOURS.
Between 6 and 7 A.M.	3·735	26·77
„ 7 „ 8 „	5·209	19·19
„ 8 „ 9 „	6·192	16·14
„ 9 „ 10 „	6·438	15·53
„ 10 „ 11 „	7·076	14·13
„ 11 „ 12 „	7·764	12·88
„ 12 „ 1 P.M.	5·995	16·68
„ 1 „ 2 „	5·946	16·82
„ 2 „ 3 „	6·388	15·64
„ 3 „ 4 „	7·862	12·72
„ 4 „ 5 „	5·209	19·19
„ 5 „ 6 „	6·290	15·90
„ 6 „ 7 „	3·685	27·13
„ 7 „ 8 „	5·012	20·00
„ 8 „ 9 „	3·047	32·81
„ 9 P.M. 6 A.M.	14·152	68·26
	100·000	

It has been the practice in the author's department to consider that one-half the total supply is used between 6 A.M.

and 9 A.M. and 3 P.M. and 6 P.M. or in six hours; some engineers consider eight hours as applicable to Indian conditions. It is, however, believed that the higher figure of demand is the one which should be adopted especially in pumping schemes, because if the demand is less than anticipated, the cost of pumping will be much reduced; whereas, if an error is made in the other direction, the cost of pumping is very much increased and as this charge is a continuous one, the error may turn out to be very expensive.

The amount of water required by the population of towns varies considerably in one town from another. For England, the following is a detail of the daily amount required for all purposes :—

	GALLONS.
Domestic supply (without baths or closets) ..	12
Baths	4
Water closets	6
Unavoidable waste	3
	25
Town and trade purposes	5
Exceptional manufacturing town extra ..	5
Total ..	35

The average for London and other towns in Britain is as follows :—

	GALLONS.
London	29
Liverpool	23
Manchester	20
Edinburgh	40
Glasgow	50
Dublin	35

The average supply to 46 English towns in 1888 was 25 gallons per head, 20 gallons being for domestic purposes.

Quantity of water required.—The following table, partially extracted from *Indian Engineering*, shows the amount of water supplied per head in Indian towns; that amount in many towns bears a very small proportion to what is used in England. The author, however, is inclined to think that, though allowing for waste the amounts do not generally exceed 9 to 10 gallons per head, these figures are due (1) to imperfect distribution, (2) to a continued use of wells from which supplies had been obtained previous to the

introduction of a pipe supply, (3) to prejudices against the use of pipe water; where manufactories do not exist in a town and when the water-supply is not available inside each house, no doubt the demand will be less than in England; but if the larger towns in India are turned to, it is found that the average demand per head is rapidly approaching English figures. Fifteen gallons per head (allowing for an increase of population) is then none too ample a supply and if this quantity be decided on for a town, 30 gallons per head per diem is the quantity the mains must be proportioned to carry. An amount for fire extinction is in many countries added to this, so that sufficient water may be always available for fire hose. This, in India, is hardly necessary, and the only point to be noticed in regard to it is that no main should be laid in any street to which a hydrant cannot be affixed; this fixes the minimum size of main at 3 inches diameter.

Consumption of Water per capita in Indian Towns.

Name of town.	Population.	Supply for which project designed.	Supply actually used.	Authority.	Remarks.
		GALS.	GALS.		
Khandwa	12,000	.....	$3\frac{1}{2}$	Report by Executive Engineer, 1881.	Supply considered insufficient.
Jabalpur	75,000	10 in 12 hours ...	39·0 British troops ... 4·3 Native troops ... 6·0 Native troops ...	Report by Executive Engineer. Report of a second test.	Of the 39 gallons, 26 were being used for gardens.
Ulsoor, Bangalore ...	3,000	10, first estimate.	1,300 English, 2,150 Natives } 30,000 in 1870.	Rurki Prof. Papers, 2nd series, vol. ix., No. 38.	
		14, English. 1 Native. } Second estimate.	1,198 English, 1,302 Natives } 43,460	Do. do. ...	Filters leaking.
Ootacamund ...	North 9053 South 6000	20 ... ... 20	20 ... ... 20	.....	
Calcutta in 1893–94...	681,560	.....	20,000,000 per diem (Filtered water).	Municipal Report.	
Bombay.					
Vehar works ...	800,000	9 mill gallons per diem.	.....	Municipal Report ...	Pawai works constructed as insurance against failure of monsoon in 1890, pending completion of Tansa supply.
Tulsi ,, ...		$4\frac{1}{2}$ Do.			
Pawai		$4\frac{1}{3}$ Do.			
Tansa ,, ...		31 Do.			

Nagpur	98,000	15 gallons in 24 hours.	7½ gallons	Blue Book Nagpur water works, and Executive Engineer's report.	
Rawalpindi	30,000	20	.....	Indian Engineer for 16th April 1887.	
Jaipur	...	.....	253,000 gallons in 1878.	R.P.P., 2nd series, vol. viii., No. 33.	Includes 6,300 gallons given to one public garden; streets not watered but bathing tanks in city filled.
Sholapur	50,666	5	4·52 in 1881	Records of Government of India.	By actual measurement from May to December.
Pandharpur	16,917 and 800 average floating.	.....	9·37 maximum ... } 6·48 minimum ... }	On fixed population only. } R.P.P., 2nd series, vol. x., No. 42.	
Dacca	75,000	2, as bathing not allowed at hydrants.	35,000 per diem, but distribution very defective.	R.P.P., 2nd series, vol. xi., No. 43.	
Darjeeling	3,000	10	.....	R.P.P., 2nd series, vol. x., No. 42.	
Jalgaon	8,406	.....	89 possible	R.P.P., 2nd series, vol. x., No. 41.	
Lahore	128,000	10	325,000 gallons average.	R.P.P., 3rd series, vol. i., No. 40.	Gauged from 24th August 1881 to 23rd January 1882.
Thana	15,000	.....	3 to 4 in warm weather. } By meter. 2½ in cold do. }	Selections from Records of Government of India, No. 253.	
Poona Cantonment ...	36,000	.....	18 in warm weather. } 11 in cold do. }	Do. do. ...	Includes for roads, gardens, &c., mixed population, Europeans and Natives.

Consumption of Water per Capita in Indian Towns—continued.

Name of town.	Population.	Supply for which project designed.	Supply actually used.	Authority.	Remarks.
		GALS.	GALS.		
Kirkee Cantonment...	8,000	.....	47	Selections from records of Government of India, No. 253.	Small Armour and Gunpowder factory, and garden and grounds of Government House included in amount per head.
Bhiwudy	12,000	10	.....	Do. do.	
Burdwan	...	.....	19,500 persons supplied with 7·5 gallons per head daily.	Records of Government of India.	
Mhow	38,000	.....	5¾	Selections from records of Government of India, No. 267.	Both European and Native population in average.
Almora	8,000	2	.....	R.P.P., 2nd series, vol. ix., No. 38.	
Ahmedabad	111,680	.....	5	Do. do. ...	Actuals calculated only on population really drawing; includes considerable waste from taps not turned off.
Simla	...	4	.....	Punjab Administration Report for 1885–86.	
Peshawar	...	5 in 8 hours ...			
Karendwad	1,000	5	.....	R.P.P., 2nd series, vol. ix., No. 38.	

Inchalkaranji ...	8,000	5	.....	Do. do. ...	Wind engine provided at first did not work, proved failure, and steam engine then provided to raise 10 gallons.
Aden	...	.....	13·3 {European officers and family.}	Do. do. ...	This supply is condensed water for drinking and cooking purposes only. Separate water for bathing and other sanitary purposes.
Secunderabad (Trimulgherry).	3,719 men. 140 officers.	.....	5, European men and family. 3·25, Natives and family. 16, per man ... 80, per officer ...	R.P.P., 2nd series, vol. ix., No. 38.	This supply is for domestic use and apparently includes allowance for women and children and followers, for whom no separate allowance. Other water is supplied for plunge baths, tatties, gardens, flushing drains, &c.
Presidency Bazaars, Chudderghat.	16,000	10 gallons in 12 hours.	.....	Report in estimate for works.	
Alebagh	5,500	16	.....	R.P.P., 2nd series, vol. ix., No. 38.	The allowance is inclusive of amount lost from storage reservoirs by evaporation and percolation.
Pen	6,000	27	.....	Do. do.	
Kolharpur	40,000	10 ...	10, in cold weather ... 2·8, in warm weather.	Do. do. ...	Small actual supply is owing to springs not yielding more.
Prome	30,000	10	.....	Burmah Administration Report for 1883–84.	
Madras	452,000	25	5·3 millions daily ...	Municipal Report, 1894–95.	This equals 11·8 gallons per head daily; portions of the town badly supplied.

Consumption of Water per Capita in Indian Towns—continued.

Name of town.	Population.	Supply for which project designed.	Supply actually used.	Authority.	Remarks.
		GALS.	GALS.		
Hyderabad (Sind) ...	3,141, cantonments.	.....	21·15, May 13, Jan. Troops	Selections from records of Government of India, No. 251, Part I.	The consumption by troops includes watering of streets and house services for officers and officials and for 2,000 of the town inhabitants. The rate for town is not quite right, as 1,000 did not draw on account of caste prejudices and 2.000 took supply from cantonments.
	44,968, town.	.....	5·50, May 3·50, Jan. Town ...		

In Indian water-supply schemes, especially in cantonments, certain pipes convey water to Cavalry lines, &c. The following are the minimum quantities which should be allowed for:—

	GALLONS PER DIEM.
Elephants	25
Camels	10
Oxen	6
Horses	8½
Mules and ponies	5

In the Madras Presidency, the author's endeavour has been to make provision, if possible, for a supply of 15 gallons per head per diem to up-country towns; this has been found to be ample and for very small towns, perhaps, a ten-gallon supply would be sufficient; where towns are unsewered, it is well at any rate in the first instance to limit the supplies; sewered towns and towns with trades requiring water for manufacturing purposes necessarily will require a more ample supply, and it is always necessary to design works in view to a considerable increase in population.

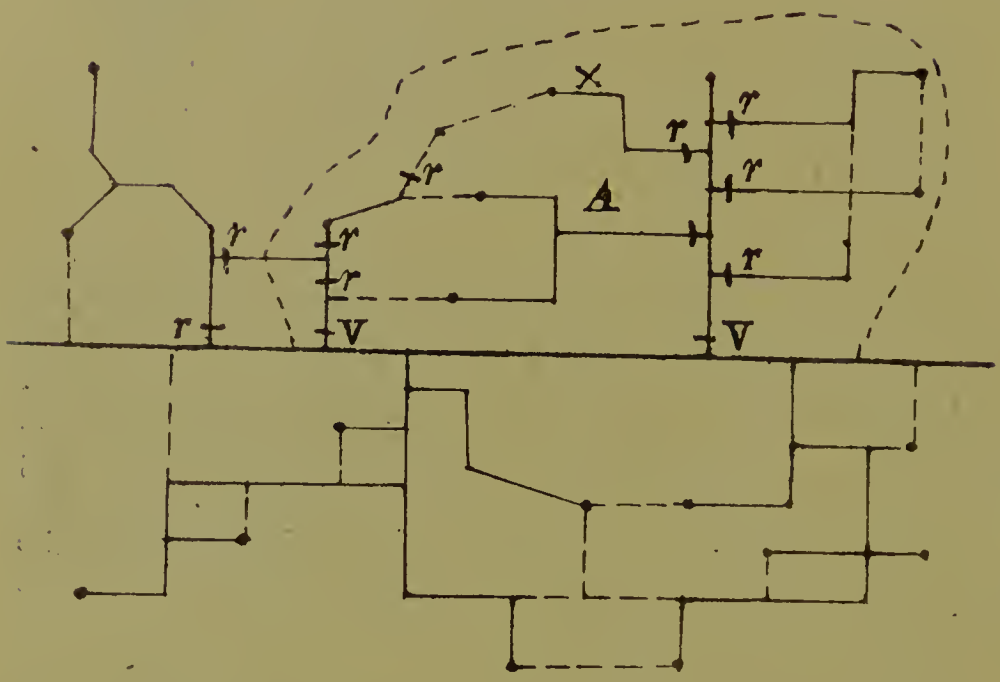
Distribution systems.—There are two systems of distribution which are applicable to India, the 'Dead-end' and the 'Grid-iron' systems. The systems may be illustrated as shown on the following page.

The two systems may be combined.

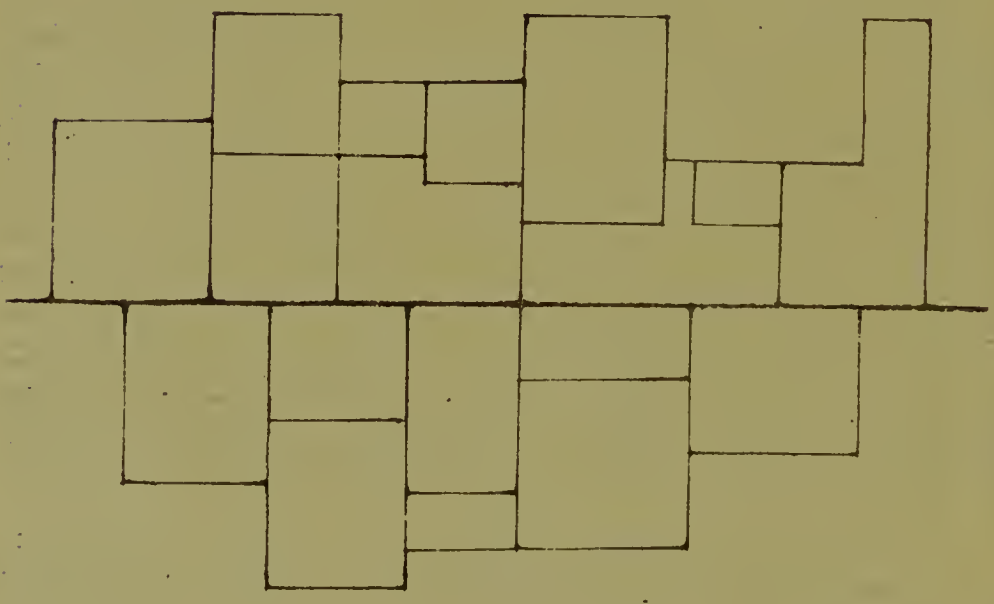
'Dead-end' system.—It will be observed that in the 'Dead-end' system, the water, once it has left the main, cannot return again, and, if not drawn off, the water must remain stagnant in the pipes. When such a system is adopted, (but in India, its use should be limited as far as possible), the dead-ends should be provided with hydrants or scour valves. The system is one that lends itself to an easy determination of the proper sizes of the pipes and a lesser number of sluice valves are required than in 'Grid-iron' system; but there is this disadvantage that the water is supplied from one direction only, and that therefore when anything goes wrong on the branch pipe, the whole population supplied by that branch may have to be temporarily deprived of their supply.

'Grid-iron' system.—With the 'Grid-iron' system, water can always be supplied from at least two directions and a full supply can be given if the pipes are proportioned in that view.

DEAD-END



GRID-IRON



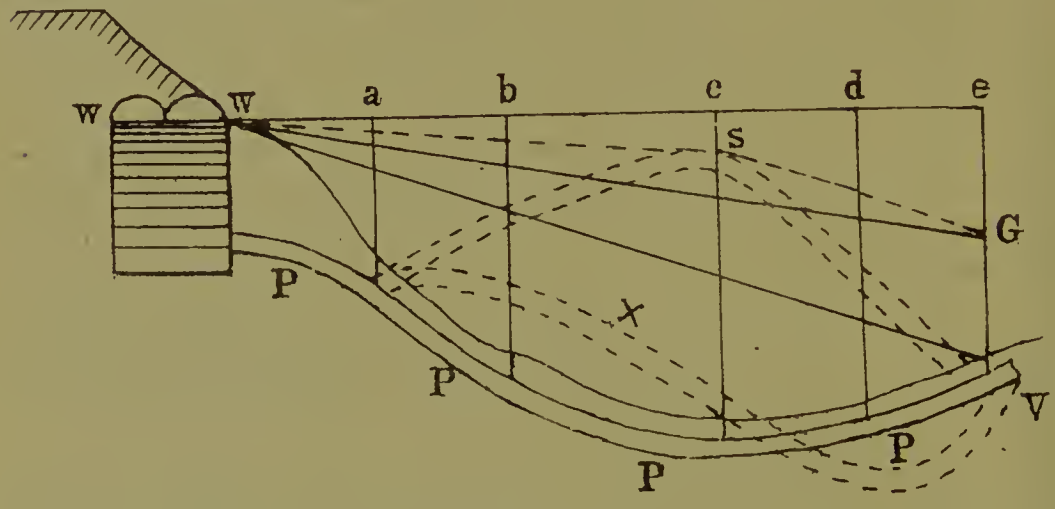
Combined system.—The author, however, believes that except in the largest towns in India, it is sufficient to have a modified system or a combination of the two foregoing determining the sizes of the mains under the condition of water flowing from one side only, but connecting the ends of all pipes together by pipes not less than 3 inches in diameter, so that stagnation is avoided and a partial supply at any rate always available. Such a system requires a larger number of valves than in the dead-end system, unless very extensive districts are to be shut off from supply during any burst, repairs, &c. The number of valves required depends a good deal on the security and amount of convenience aimed at. For instance, in the district *A*, if a burst occurred at any point in the district, then if there were no other valves than those near the main VV, the whole of the persons in the district would be without water; but if valves are also available at the points marked *r* then only the particular pipe where the burst occurred would be cut off from the supply.

Position for mains and pipes.—In an irregularly-built town with few definite main streets, it is a matter of judgment and experience as to how the pipes should be arranged. In India, where the major part of the supply is derived from the street stand pipes, it is necessary to be guided by two factors: *firstly*, the distribution of the stand pipes ought to be averaged over the town area, so that no person may be beyond a fixed distance from a stand pipe or fountain; *secondly*, the supply to each such stand pipe or fountain should be in proportion to the population served by it, thus at fountains in densely-populated districts, two, three or four taps may be required.

Flow of water in pipes.—The flow of water in closed pipes under pressure differs from that in conduits in so far that the water wholly fills a pipe, but seldom a conduit; there is no air surface in a pipe, as the water is under some pressure and therefore the bottom line of the pipe need not follow any line parallel to a free flowing surface as in an ordinary open or arched conduit. Pipes are seldom laid at a level near that of the hydraulic gradient; but where stoneware or cement pipes are used, it is desirable that they should be arranged, so that they approach closely to the hydraulic gradient.

Hydraulic gradient.—The hydraulic gradient of any pipe may be represented by a line drawn through a series of points to which the water in a pipe would rise, if pipes were vertically inserted in the main to allow of its doing so; thus in the following diagram, suppose PPPP a pipe of uniform

bore laid from a reservoir, the water surface of which is at W W, then if V is a valve closed and vertical pipes were inserted as a b c d e, the water would rise in these pipes to the same level as the water surface W W, in the reservoir, if it remains at that level as will be supposed. If however the valve V be slightly opened, a flow will take place through the pipe and the hydraulic gradient or line of pressures will fall below the line a b c d e, in proportion to the loss of head caused by friction of the water in the pipes (other losses being small and negligible) and the hydraulic grade would assume a position such as W G. If the valve V were fully opened, the hydraulic gradient would be along the line W V. The distance between the pipe line and the hydraulic gradient is the pressure or head over the pipe. With pipes of uniform bore, the hydraulic grade is a straight line so long as the pipe line does not rise above the grade; the pipe may be laid at any level without causing an alteration in the hydraulic gradient; thus the hydraulic gradient would be the same for a pipe (X) laid as shown by dotted lines:—

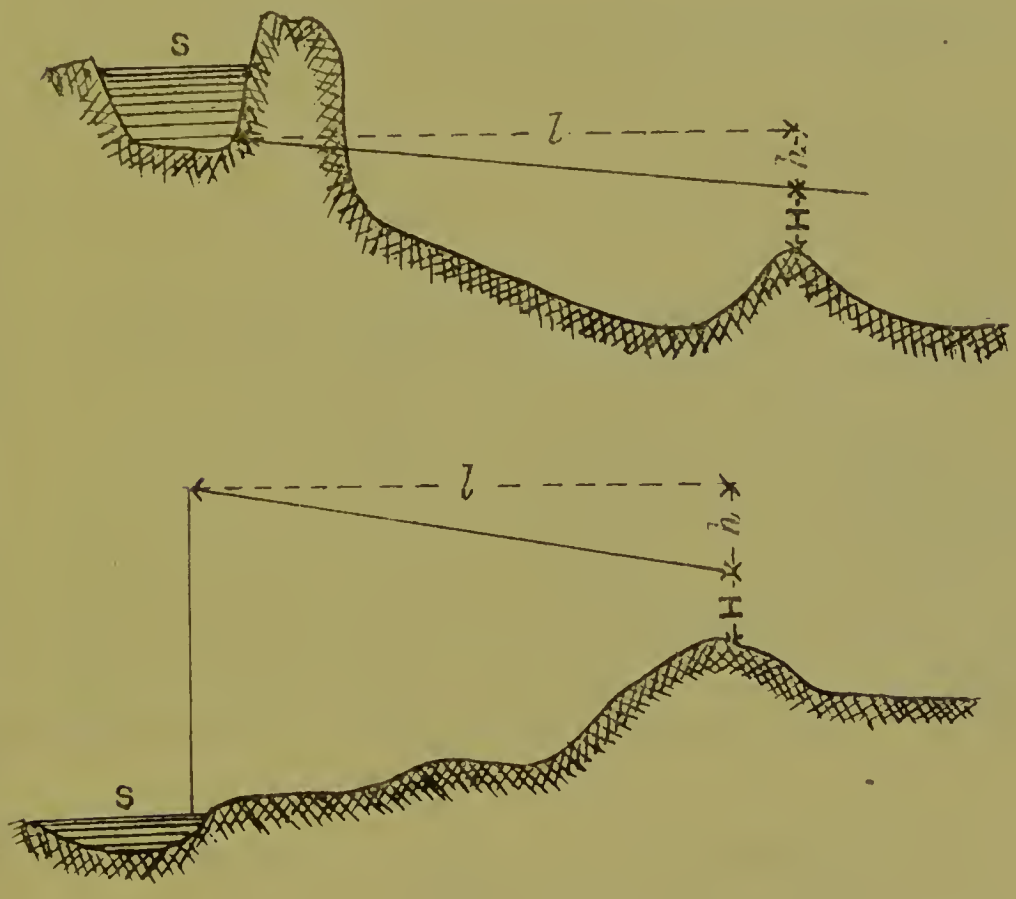


If a pipe rises above the hydraulic gradient as, for instance, to a point S, air will tend to get into the pipe, and the gradient instead of being a straight line will be from W to S and S to G.

Amount of pressure desirable.—The greater the head or pressure always available over the pipe in a town, the greater are the facilities for the supply of water to high buildings and upper floors and for fire purposes; high pressure often means considerable cost, and thus it is desirable that there should be some minimum pressure fixed. In pumping schemes especially it is desirable to fix the pressure at a minimum and maintain only such pressure as will meet ordinary

demands. A minimum of 10 feet under maximum demand has been that fixed for pumping schemes drawn up by the author, and this is as low as consistent with possible variation of demand while meeting all ordinary requirements. The minimum head or pressure must be fixed either in reference to the highest part of the town (if intervening) or at that part of the town furthest from the source.

Loss of head.—The first of the two following diagrams shews a gravitation, the second a pumping scheme:—



The 'loss of head' is represented in each case by h, and the hydraulic gradient is $\frac{h}{l}$, from which basis the diameters of the various sizes of pipes have to be determined.

Determination of the sizes of pipes.—There are two conditions which may present themselves, one being the case in which the position and level of the reservoir have already been fixed, and when therefore the average hydraulic grade can be at once determined; the other case being that in which the level of the reservoir is to be fixed after the hydraulic

gradients are arranged. Taking, for example, the former case and having decided upon the minimum amount of pressure to be maintained over the highest point of the town area, an approximate hydraulic gradient, for instance W G in the figure on page 340 *ante*, is obtained with reference to the maximum flow through the pipes. It is usual to limit the flow of water through pipes to certain maximum velocities which should not be exceeded, and if these are determined, the maximum discharge allowable and the maximum hydraulic gradients at which such pipes ought to be laid are also known. These are exhibited in the following table :—

Diameter of pipes in inches.	2	2½	3	4	5	6	7	8	9	10
Velocities in feet per second ...	3·1	3·1	3·3	3·6	3·9	4·2	4·5	4·8	5·0	5·2
Grade in length of 1,000 ft. ...	21·60	17·28	15·68	13·74	12·72	12·16	11·89	11·50	11·16	10·91
Discharge in gallons per minute ...	25·34	39·64	60·76	117·72	199·33	309·17	450·00	619·20	828·37	1063·53

Diameter of pipes in inches.	12	14	15	16	18	20	21	22	24
Velocities in feet per second ...	5·5	5·8	6·0	6·0	6·2	6·5	6·5	6·6	6·7
Grade in length of 1,000 ft. ...	10·13	9·34	9·34	8·78	8·38	8·18	7·98	7·83	7·19
Discharge in gallons per minute ...	1619·88	2324·64	2761·20	3143·25	4108·74	5317·65	5862·67	6534·00	7893·27

If the gradient were, say, $\frac{12·16}{1000}$ and a supply of 309·17 gallons per minute were required, it would be seen at once that a 6-inch pipe would be necessary, but matters do not always adjust themselves like this: for instance, it may be desirable to give a grade of $\frac{20}{1000}$, and supposing a flow of 1,134 gallons per minute is required, a 9-inch pipe would carry the required amount; but the velocity would be 6·86 feet per second; and therefore the grade must be flattened and the size of pipe increased. The diameters of the pipes should therefore be fixed not only with reference to the quantity they are required to carry, but in regard to the maximum velocities tabulated above; thus in a town supply as the pipes decrease in diameter, the further they are away from the

source, by varying the diameter of the pipes it may be possible to lay them, so that the approximately fixed hydraulic gradient can be nearly maintained; but the gradient finally arranged will often be at some places above and at others below that approximately decided upon. If, in the immediate future, there is likely to be any greatly increased draught in the pipes, their sizes ought to be fixed with reference to that augmented amount, so that the increased demand will not entail a reduction of pressure below the minimum head decided upon as necessary.

The following formulæ afford easy methods of determining the velocity, size or discharge of pipes:—

$$V = \frac{G}{2{\cdot}04d^2}$$

$$d = \sqrt{\frac{G}{2{\cdot}04v}}$$

$$G = 2{\cdot}04\ vd^2$$

where V = velocity in feet per second,
d = diameter of pipe in inches,
G = imperial gallons per minute discharged.

By the use of tables such as those following much labour is avoided, and as likely to minimise error, their use is advocated. Unless, therefore, special sizes of mains not included in the tables are required, or the main is a long main of large diameter requiring special calculations in reference to it, tables should be used. The following were compiled in and are in use in the author's department and have been found to give satisfactory results:—

from Neville's Formula $v = 140\sqrt{rs} - 11\sqrt[3]{rs}$.

Diameter of Pipes in inches.		2		2½		3		4		5		6		7		8		Diameter of Pipes in inches.
Inclination of pipe.	Head in a length of 10,000 feet.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Head in a length of 10,000 feet.	Inclination of pipe.
1 in 10,000	1	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1	1 in 10,000
,, 5,000	2	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2	,, 5,000
,, 3,333	3	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	3	,, 3,333
,, 2,500	4	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	4	,, 2,500
,, 2,000	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5	,, 2,000
,, 1,667	6	...	...	...	...	...	...	·585	19·090	·670	34·195	·749	54·985	·821	82·120	·889	116·152	6	,, 1,667
,, 1,429	7	...	...	...	...	...	...	·643	20·984	·736	37·541	·821	60·333	·900	90·029	·975	127·292	7	,, 1,429
,, 1,250	8	...	...	...	...	...	...	·697	22·760	·798	40·684	·889	65·336	·974	97·458	1·055	137·727	8	,, 1,250
,, 1,111	9	...	...	...	...	...	...	·749	24·438	·856	43·658	·954	70·074	1·045	104·477	1·130	147·587	9	,, 1,111
,, 1,000	10	·522	4·264	·600	7·647	·670	12·310	·798	26·038	·911	46·489	1·015	74·577	1·112	111·156	1·202	156·977	10	,, 1,000
,, 909	11	·554	4·523	·636	8·106	·710	13·043	·844	27·569	·964	49·193	1·074	78·882	1·176	117·536	1·271	165·949	11	,, 909
,, 833	12	·585	4·772	·670	8·549	·749	13·746	·889	29·038	1·015	51·790	1·130	83·018	1·237	123·655	1·337	174·555	12	,, 833
,, 769	13	·614	5·013	·704	8·975	·786	14·426	·933	30·455	1·064	54·294	1·184	87·007	1·296	129·554	1·400	182·835	13	,, 769
,, 714	14	·643	5·246	·736	9·385	·821	15·083	·975	31·823	1·112	56·712	1·237	90·849	1·353	135·254	1·461	190·840	14	,, 714
,, 667	15	·670	5·471	·768	9·799	·886	15·717	1·015	33·145	1·158	59·049	1·287	95·573	1·408	140·763	1·521	198·585	15	,, 667
,, 625	16	·697	5·690	·798	10·171	·889	16·334	1·055	34·432	1·202	61·319	1·337	98·187	1·461	146·112	1·578	206·107	16	,, 625
,, 588	17	·723	5·903	·827	10·598	·922	16·934	1·093	35·682	1·245	63·528	1·384	101·699	1·513	151·322	1·634	213·407	17	,, 588
,, 556	18	·749	6·109	·856	10·914	·954	17·526	1·130	36·897	1·287	65·676	1·432	105·159	1·564	156·381	1·689	220·512	18	,, 556
,, 526	19	·773	6·313	·884	11·273	·985	18·088	1·167	38·085	1·329	67·777	1·476	108·450	1·613	161·310	1·742	227·434	19	,, 526
,, 500	20	·798	6·509	·911	11·622	1·015	18·644	1·202	39·244	1·369	69·818	1·521	111·704	1·662	166·130	1·793	234·198	20	,, 500
,, 455	22	·844	6·892	·964	12·298	1·074	19·720	1·271	41·487	1·446	73·782	1·606	118·000	1·755	175·449	1·891	246·958	22	,, 455
,, 417	24	·889	7·260	1·015	12·947	1·130	20·754	1·337	43·639	1·521	77·572	1·688	124·031	1·844	184·377	1·990	259·821	24	,, 417
,, 385	26	·933	7·614	1·064	13·574	1·184	21·752	1·400	45·709	1·592	81·230	1·768	129·849	1·930	192·966	2·082	271·888	26	,, 385
,, 357	28	·975	7·956	1·112	14·178	1·237	22·712	1·461	47·710	1·662	84·760	1·844	135·461	2·013	261·265	2·171	283·538	28	,, 357
,, 333	30	1·015	8·286	1·158	14·762	1·287	23·643	1·521	49·646	1·728	88·173	1·918	140·890	2·093	209·294	2·257	294·808	30	,, 333
,, 286	35	1·112	9·074	1·267	16·152	1·408	25·854	1·662	54·246	1·887	96·284	2·093	153·767	2·284	228·352	2·462	321·554	35	,, 286
,, 250	40	1·202	9·811	1·369	17·455	1·521	27·926	1·793	58·550	2·036	103·870	2·257	165·830	2·462	246·190	2·654	346·590	40	,, 250
,, 200	50	1·369	11·171	1·557	19·853	1·728	31·742	2·036	66·477	2·310	117·843	2·560	188·022	2·790	278·996	3·006	392·625	50	,, 200
,, 167	60	1·521	12·412	1·728	22·043	1·918	35·222	2·257	73·702	2·560	130·571	2·835	208·238	3·089	308·882	3·327	434·520	60	,, 167
,, 143	70	1·662	13·562	1·887	24·071	2·093	38·442	2·462	80·389	2·790	144·345	3·089	226·934	3·366	336·509	3·624	473·268	70	,, 143
,, 125	80	1·793	14·637	2·036	25·967	2·257	41·457	2·654	86·647	3·006	153·369	3·327	244·418	3·624	362·346	3·901	509·508	80	,, 125
,, 111	90	1·918	15·654	2·177	27·759	2·412	44·304	2·835	92·550	3·210	163·756	3·552	260·910	3·868	386·713	4·163	543·673	90	,, 111
,, 100	100	2·036	16·619	2·310	29·461	2·560	47·006	3·006	98·156	3·403	173·622	3·765	276·564	4·099	409·840	4·411	576·100	100	,, 100
,, 83	120	2·257	18·426	2·560	32·643	2·835	52·060	3·327	108·630	3·765	192·058	4·166	306·029	4·531	453·045	4·875	636·670	120	,, 83
,, 71	140	2·462	20·097	2·790	35·586	3·089	56·735	3·624	118·317	4·099	209·102	4·531	332·849	4·930	492·980	5·304	692·631	140	,, 71
,, 63	160	2·654	21·662	3·006	38·342	3·327	61·104	3·901	127·377	4·411	225·039	4·875	358·127	5·304	530·295	5·704	744·948	160	,, 63
,, 56	180	2·835	23·138	3·210	40·933	3·552	65·227	4·163	135·918	4·706	240·063	5·199	381·950	5·656	565·481	6·082	794·235	180	,, 56
,, 50	200	3·006	24·539	3·403	43·405	3·765	69·141	4·411	144·025	4·985	254·316	5·507	404·554	5·989	598·857	6·440	841·001	200	,, 50

Table showing the Velocity in feet per second and Supply in gallons per minute from Neville's Formula $v = 140\sqrt{rs} - 11\sqrt[3]{rs}$ — continued.

Diameter of Pipes in inches.		9		10		12		14		15		16		18		20		Diameter of Pipes in inches.
Inclination of pipe.	Head in a length of 10,000 feet.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Inclination of pipe.
1 in 10,000	1	...	...	...	...	...	...	·413	165·180	·436	200·226	·454	237·320	·489	323·366	·522	426·397	1 in 10,000
,, 5,000	2	...	...	...	...	·585	171·809	·643	257·049	·670	307·753	·697	364·155	·749	494·866	·798	650·541	,, 5,000
,, 3,333	3	...	...	...	...	·749	219·941	·821	328·480	·856	392·922	·889	464·619	·954	630·665	1·015	828·634	,, 3,333
,, 2,500	4	...	...	·798	162·735	·889	261·343	·975	389·832	1·015	466·107	1·055	550·908	1·130	747·159	1·202	981·105	,, 2,500
,, 2,000	5	·856	141·452	·911	185·957	1·015	298·308	1·112	444·626	1·158	531·140	1·202	627·907	1·287	851·157	1·369	1117·09	,, 2,000
,, 1,667	6	·954	157·666	1·015	207·158	1·130	332·071	1·273	494·620	1·287	591·081	1·337	698·220	1·431	946·097	1·521	1241·15	,, 1,667
,, 1,429	7	1·045	172·707	1·112	226·805	1·237	363·394	1·353	541·014	1·408	646·360	1·461	763·362	1·564	1034·03	1·662	1356·16	,, 1,429
,, 1,250	8	1·130	186·790	1·202	245·276	1·337	392·749	1·461	584·449	1·521	698·150	1·568	824·429	1·689	1116·34	1·793	1463·74	,, 1,250
,, 1,111	9	1·211	200·128	1·287	262·703	1·431	420·487	1·564	625·524	1·627	747·093	1·689	882·048	1·806	1194·09	1·918	1565·44	,, 1,111
,, 1,000	10	1·287	212·789	1·369	279·272	1·521	446·816	1·662	664·519	1·728	793·357	1·793	936·794	1·918	1268·01	2·036	1661·92	,, 1,000
,, 909	11	1·361	224·905	1·446	295·127	1·606	471·998	1·755	701·794	1·825	837·954	1·894	989·137	2·025	1338·55	2·140	1754·15	,, 909
,, 833	12	1·431	236·524	1·521	310·289	1·689	496·152	1·844	737·510	1·918	880·561	1·990	1039·29	2·127	1406·19	2·264	1848·02	,, 833
,, 769	13	1·499	247·698	1·592	324·920	1·768	519·394	1·930	771·866	2·007	921·515	2·082	1087·55	2·225	1471·31	2·362	1927·60	,, 769
,, 714	14	1·564	258·507	1·662	339·040	1·844	541·844	2·013	805·062	2·093	961·046	2·171	1134·15	2·320	1534·12	2·462	2009·71	,, 714
,, 667	15	1·627	268·953	1·728	352·692	1·918	563·559	2·093	837·178	2·177	999·338	2·257	1179·23	2·412	1594·94	2·560	2089·13	,, 667
,, 625	16	1·689	279·085	1·793	365·935	1·990	584·598	2·171	868·334	2·257	1036·44	2·341	1222·96	2·502	1658·85	2·654	2166·18	,, 625
,, 588	17	1·748	288·936	1·856	378·811	2·059	605·079	2·247	898·610	2·336	1072·48	2·422	1265·43	2·588	1711·11	2·745	2240·87	,, 588
,, 556	18	1·806	298·523	1·918	391·361	2·127	624·972	2·320	928·047	2·412	1107·60	2·502	1306·75	2·672	1766·84	2·835	2313·76	,, 556
,, 526	19	1·863	307·862	1·978	403·563	2·193	644·365	2·392	956·763	2·487	1141·80	2·579	1347·07	2·755	1821·12	2·922	2384·61	,, 526
,, 500	20	1·918	317·002	2·036	415·480	2·257	663·318	2·462	989·760	2·560	1175·14	2·654	1386·36	2·835	1874·14	3·006	2453·91	,, 500
,, 455	22	2·025	334·638	2·149	438·538	2·382	699·931	2·598	1038·93	2·700	1239·64	2·799	1462·26	2·990	1976·49	3·170	2587·52	,, 455
,, 417	24	2·125	351·216	2·264	462·005	2·502	735·045	2·727	1090·83	2·835	1301·49	2·939	1535·13	3·138	2074·67	3·327	2715·75	,, 417
,, 385	26	2·225	367·827	2·362	481·900	2·616	768·807	2·852	1140·74	2·964	1360·95	3·073	1605·13	3·281	2160·01	3·478	2839·08	,, 385
,, 357	28	2·320	383·530	2·462	502·428	2·727	801·424	2·973	1188·89	3·089	1418·34	3·202	1672·73	3·419	2260·12	3·624	2957·93	,, 357
,, 333	30	2·412	398·736	2·560	522·283	2·835	832·953	3·089	1235·53	3·210	1473·80	3·327	1738·08	3·552	2348·18	3·765	3072·93	,, 333
,, 286	35	2·631	434·785	2·799	570·883	3·089	907·776	3·336	1346·04	3·497	1605·43	3·624	1893·07	3·868	2557·04	4·099	3345·63	,, 286
,, 250	40	2·835	468·536	3·006	613·476	3·327	977·670	3·624	1449·38	3·765	1728·52	3·901	2038·03	4·163	2752·34	4·411	3600·62	,, 250
,, 200	50	3·210	530·568	3·403	694·487	3·765	1106·26	4·099	1639·36	4·258	1954·78	4·411	2304·40	4·706	3111·21	4·985	4069·05	,, 200
,, 167	60	3·552	587·046	3·765	768·233	4·163	1223·26	4·531	1812·18	4·706	2160·56	4·875	2546·68	5·199	3437·55	5·507	4495·04	,, 167
,, 143	70	3·868	639·260	4·099	836·408	4·531	1331·40	4·930	1971·92	5·120	2350·73	5·304	2770·52	5·656	3739·10	5·989	4888·63	,, 143
,, 125	80	4·163	688·085	4·411	900·156	4·875	1432·51	5·304	2121·18	5·507	2528·46	5·704	2974·79	6·082	4020·81	6·440	5256·26	,, 125
,, 111	90	4·442	734·118	4·706	960·250	5·199	1527·80	5·656	2261·92	5·872	2695·95	6·082	3176·94	6·483	4286·39	6·864	5602·75	,, 111
,, 100	100	4·706	777·803	4·985	1017·26	5·507	1618·22	5·989	2395·43	6·218	2854·86	6·440	3364·00	6·864	4538·22	7·267	5931·44	100 ,, 100

Table showing the Velocity in feet per second and the supply in Gallons per minute for Long Pipes flowing full calculated from Neville's Formula $v = 140\sqrt{rs} - 11\sqrt[3]{rs}$—continued.

Diameter of Pipes in inches.		21		22		24		27		30		33		36		Diameter of Pipes in inches.	
Inclination of pipe.	Head in a length of 10,000 feet.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Velocity in feet per second.	Supply in galls. per minute.	Head in a length of 10,000 feet.	Inclination of pipe.
1 in 10,000	1	·538	484·501	·554	538·560	·585	687·237	·629	934·940	·670	1231·01	·710	1578·19	·749	1979·46	1	1 in 10,000
,, 5,000	2	·821	739·080	·846	837·121	·889	1045·37	·954	1419·00	1·015	1864·43	1·074	2386·17	1·130	2988·63	2	,, 5,000
,, 3,333	3	1·045	940·295	1·074	1062·993	1·130	1328·28	1·211	1801·16	1·287	2364·32	1·361	3023·72	1·431	3784·39	3	,, 3,333
,, 2,500	4	1·237	1112·89	1·271	1257·933	1·337	1571·00	1·431	2128·72	1·521	2792·60	1·606	3569·48	1·689	4465·37	4	,, 2,500
,, 2,000	5	1·408	1266·87	1·446	1431·424	1·521	1787·26	1·627	2420·58	1·728	3174·23	1·825	4055·70	1·918	5072·03	5	,, 2,000
,, 1,667	6	1·564	1407·43	1·606	1589·571	1·689	1984·61	1·806	2686·41	1·918	3522·25	2·025	4499·02	2·127	5624·75	6	,, 1,667
,, 1,429	7	1·709	1537·46	1·751	1733·034	1·844	2167·38	1·972	2933·20	2·093	3844·18	2·209	4909·24	2·320	6136·47	7	,, 1,429
,, 1,250	8	1·844	1659·40	1·893	1873·851	1·990	2338·39	2·127	3163·92	2·257	4145·74	2·382	5293·23	2·502	6615·41	8	,, 1,250
,, 1,111	9	1·972	1774·40	2·024	2004·053	2·127	2499·89	2·273	3381·70	2·412	4430·40	2·545	5655·89	2·672	7067·36	9	,, 1,111
,, 1,000	10	2·093	1883·65	2·149	2127·211	2·257	2653·27	2·412	3588·62	2·560	4700·55	2·700	5999·88	2·835	7496·58	10	,, 1,000
,, 909	11	2·209	1988·04	2·268	2245·361	2·382	2799·72	2·545	3786·17	2·700	4958·58	2·848	6328·32	2·990	7905·96	11	,, 909
,, 833	12	2·320	2088·11	2·382	2357·953	2·502	2940·18	2·672	3975·39	2·835	5205·96	2·990	6643·20	3·138	8298·68	12	,, 833
,, 769	13	2·428	2184·48	2·491	2466·085	2·616	3075·23	2·795	4157·47	2·964	5443·79	3·126	6946·08	3·281	8676·06	13	,, 769
,, 714	14	2·531	2277·26	2·597	2570·695	2·772	3205·70	2·913	4333·16	3·089	5673·35	3·257	7238·30	3·419	9040·48	14	,, 714
,, 667	15	2·631	2367·16	2·700	2672·721	2·835	3331·81	3·027	4503·18	3·210	5895·20	3·385	7520·96	3·552	9392·74	15	,, 667
,, 625	16	2·727	2454·36	2·799	2770·836	2·939	3454·05	3·138	4668·01	3·327	6110·44	3·508	7794·96	3·681	9734·15	16	,, 625
,, 588	17	2·821	2538·95	2·896	2867·356	3·040	3572·76	3·246	4828·07	3·441	6319·25	3·628	8060·95	3·806	10065·8	17	,, 588
,, 556	18	2·913	2621·29	2·979	2949·572	3·138	3688·30	3·350	4983·67	3·552	6522·74	3·744	8319·61	3·928	10388·4	18	,, 556
,, 526	19	3·002	2701·56	3·081	3049·994	3·234	3800·78	3·452	5135·25	3·660	6720·71	3·857	8571·83	4·047	10702·9	19	,, 526
,, 500	20	3·089	2779·94	3·170	3138·091	3·327	3910·68	3·552	5283·42	3·765	6914·10	3·968	8817·82	4·163	11009·4	20	,, 500
,, 455	22	3·257	2931·21	3·342	3308·324	3·508	4122·95	3·744	5569·33	3·968	7287·46	4·182	9293·15	4·387	11601·8	22	,, 455
,, 417	24	3·419	3076·27	3·508	3472·477	3·681	4326·29	3·928	5843·49	4·163	7645·40	4·387	9748·69	4·602	12169·3	24	,, 417
,, 385	26	3·574	3215·76	3·666	3629·733	3·847	4521·99	4·105	6107·09	4·350	7989·56	4·584	10186·6	4·808	12714·9	26	,, 385
,, 357	28	3·723	3350·29	3·819	3781·141	4·008	4710·52	4·276	6361·31	4·531	8321·23	4·774	10608·9	5·007	13241·4	28	,, 357
,, 333	30	3·868	3480·42	3·968	3927·888	4·163	4893·05	4·442	6607·06	4·706	8642·26	4·958	11017·3	5·199	13750·2	30	,, 333
,, 236	35	4·211	3788·99	4·319	4275·874	4·531	5325·59	4·833	7189·74	5·120	9402·94	5·394	11985·3	5·656	14956·4	35	,, 286
,, 250	40	4·531	4077·40	4·647	4600·620	4·875	5730·03	5·199	7734·49	5·507	10113·9	5·801	12890·0	6·082	16083·3	40	,, 250
,, 200	50	5·120	4607·44	5·251	5198·623	5·507	6472·86	5·872	8734·89	6·218	11419·4	6·548	14551·0	6·864	18152·9	50	,, 200
,, 167	60	5·656	5089·33	5·800	5741·932	6·082	7148·11	6·483	9644·39	6·864	12606·2	7·228	16061·0	7·575	20033·7	60	,, 167
,, 143	70	6·150	5534·51	6·307	6244·319	6·612	7772·00	7·048	10484·3	7·461	13702·2	7·855	17455·0	8·232	21770·7	70	,, 143
,, 125	80	6·612	5950·43	6·780	6712·437	7·108	8354·86	7·575	11269·0	8·019	14726·1	8·441	18757·4	8·846	23392·8	80	,, 125
,, 111	90	7·048	6342·34	7·227	7154·889	7·575	8903·87	8·072	12008·3	8·544	15690·2	8·993	19984·3	9·423	24920·6	90	,, 111
,, 100	100	7·461	6714·08	7·650	7573·870	8·019	9424·68	8·543	12709·4	9·042	16605·4	9·517	21147·6	9·971	26369·6	100	,, 100

Table shewing the supply at each Fountain

Number of ward or district	Prospective population	Supply in gallons per minute	Number of stand pipes or fountains	Delivery at each fountain	Fountain numbers as in plan
		A	B		
1	3024	63	7	9	12,13,19,20,21,43 & 45
2 & 3	10080	210	10	21	14,15,16,17,18,,22,,23,,24 25 and 44
4	11232	234	9	26	1,2,6,10,11,,47,48,49and 50
5	3744	78	3	25	3,36,and 42
6	6480	135	5	27	37,38,39,40,& 41
7	7680	160	10	16	4,5,28,29,30,31,32,33 34,and 35
	8064	168	6	28	6,7,8,9 26 and 27
	50304	1048	50	Total	

NOTE A—The daily supply is supposed to be 15 gallons per head Chalf the quantity to be delivered in 6 hrs. The supply in gallons per minute in each district = (Population in each district x 15) divided by 12 x 60

B. The fountains in each district are placed so that no person is further distant, than 450 feet from the nearest stand Pipe.

DISTRIBUTION SYSTEM

HORIZONTAL SCALE

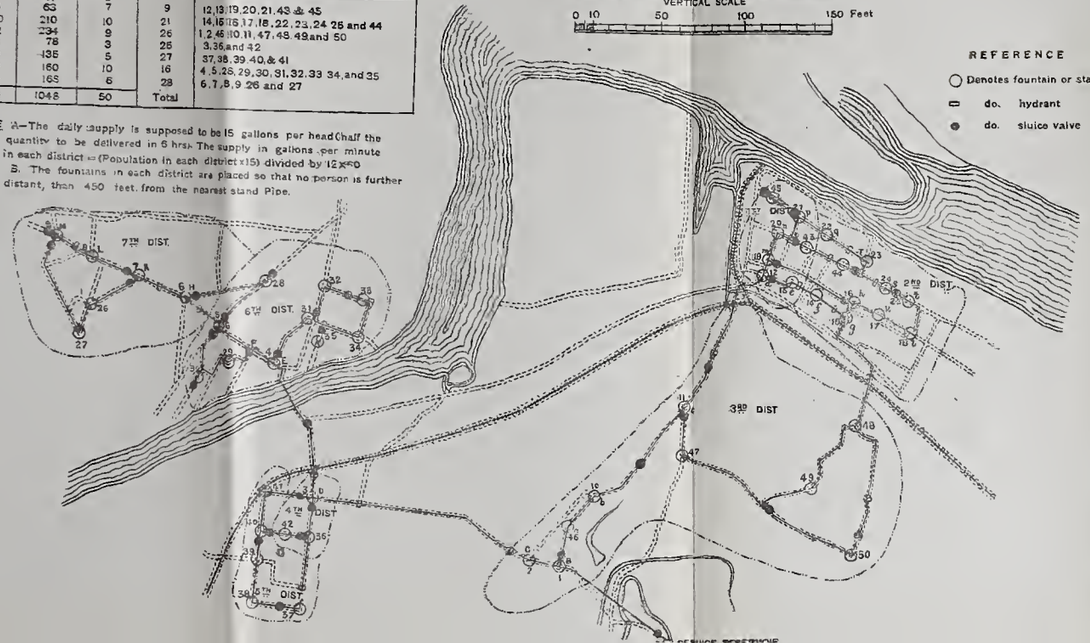
1000 0 1000 2000 3000 4000 5000 Feet

VERTICAL SCALE

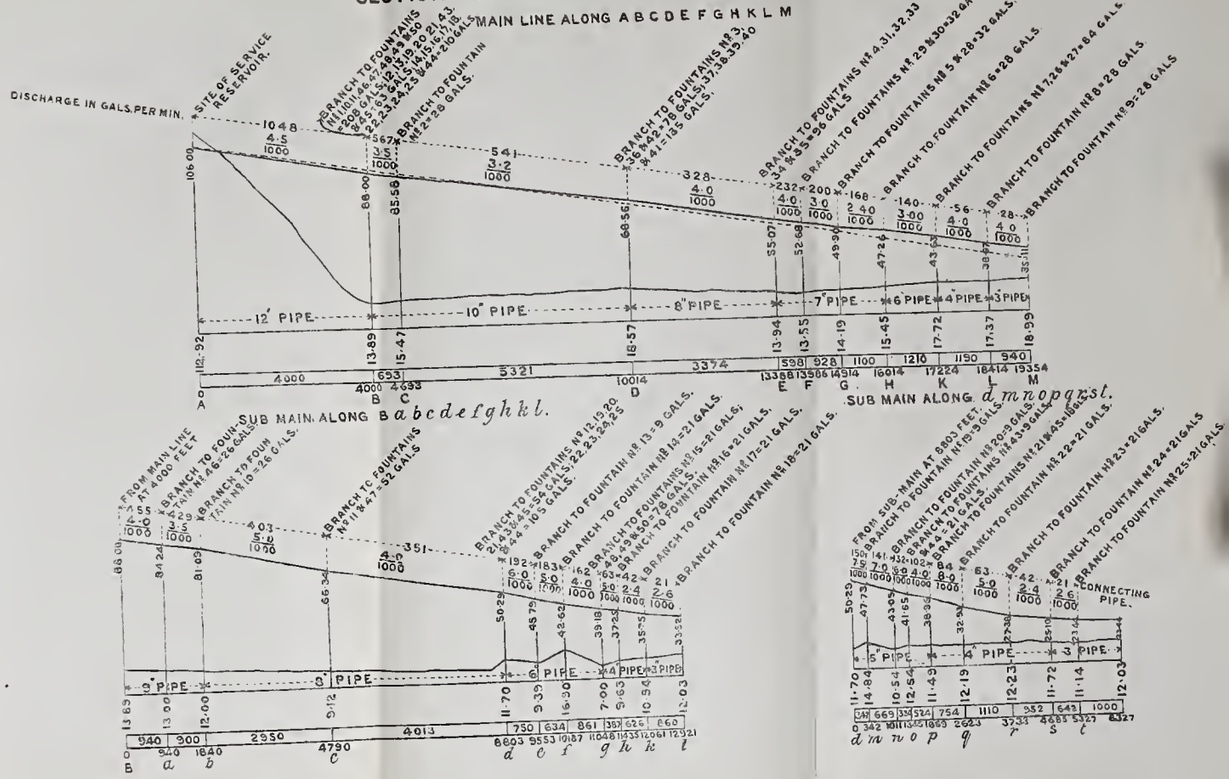
0 10 50 100 150 Feet

REFERENCE

- ◯ Denotes fountain or stand pipe
- ▭ do. hydrant
- ● do. sluice valve



SECTIONS SHEWING HYDRAULIC GRADIENTS OF PIPES



On the accompanying plate is illustrated the distribution system of a town divided into seven wards or districts with the respective and prospective population of 3024, 10080, 11232, 3744, 6480, 7680, 8064 or a total population of 50,304. The daily demand is supposed to be 15 gallons per head (half that quantity to be delivered in six hours).

The stand pipes or fountains in each district are so placed that no house is farther distant than 450 feet from the nearest stand pipe. The minimum pressure on the mains at no place is to be less than 10 feet above street level.

For the determination of the diameters of pipes from A to B, B to C, C to D, D to E, E to F, F to G, G to H, H to K, K to L, L to M, the following considerations present themselves :—

Given the lowest water level of the clear water reservoir, and the head at M which is the point furthest from the reservoir (thus the available head between A and M) and the maximum quantities of water to be delivered; find the size of pipes such that the velocities do not in general exceed those already tabulated.

The discharge through each length of pipe is determined thus :—

$$D = \frac{P \times S}{N \times 60}$$

where D = discharge in gallons per minute,
P = population to be supplied through each length of pipe,
S = supply in gallons per head per diem,
N = number of hours in which the daily supply is delivered, or if the mains are to be capable of delivering one-half the total daily supply in six hours, the above formula becomes

$$D = \frac{P \times S}{720}$$

Assuming that the clear water reservoir is located at A with its lowest water level at 106·00 above M.S.L, and that the ground level at M is 18·99, that a minimum head of 10 feet is required and that therefore the level at the end of the hydraulic grade line must not be lower than 28·99, the mean hydraulic gradient available is (106·00 — 28·99) or 77·01 feet in the length A to M or 19,354 feet or say 4·0 in a thousand.

The maximum number of gallons per minute required to flow through each pipe is then marked on the section and beginning at the reservoir a supply of 1,048 gallons is required.

By referring to tables such as those already referred to, it is found that a 12-inch pipe laid at a grade of $\frac{4{\cdot}5}{1000}$ is suitable, this grade is drawn and its level at B determined; the diameter of the length B C is similarly found and so on until the end of the main is arrived at; it will be found that the pressure is more, and the hydraulic gradient at a higher level than that of the approximate grade originally determined: this is due to the fact that pipes of the exact diameter required cannot always be used as will be explained further on.

It will be noticed that there are sub-mains whose gradients are dependent on the grade of the main, thus the level at the point B might have been fixed too low to allow of sufficient pressure, and proper gradients being obtainable on the sub-main. In such case the gradients of the main would have had to be rearranged giving a flatter grade above the point B using larger pipes, and sharper grades (if possible) with smaller pipes below B or the pressure on the whole main must be increased.

The sections so formed illustrate graphically the sizes of pipes and the hydraulic grade lines. The diameters of the main can be determined by calculation without any hydraulic gradients being actually plotted. The graphic system is believed to be the one in which mistakes are least likely to occur, and it is one which allows of a ready determination of the pressure at any point in the town and not only at the junction of the different sizes of pipes as would be the case unless a considerable number of calculations were made.

The following rules in regard to pipes are important and useful:—

(1) When the *head* and *length* of pipes remain constant, the supply varies as the square root of the fifth power of the diameter or as $\sqrt{d^5} = d^{\frac{5}{2}} = d^{2{\cdot}5}$.

(2) When the *diameter* and *length* remain constant, the supply varies as the square root of the head.

(3) When the *diameter* and *head* remain constant, the supply will be inversely as the square root of the length.

The following table (from Fanning) shows the relative discharging power of pipes of various diameters. It will be seen that the table is based on rule (1), and that for a double discharge, a pipe of double the area is not necessary; thus the discharge from a pipe of 2-feet diameter is not four times that of a pipe 1 foot in diameter, but 5·657 times, and from a pipe 4 feet in diameter not 16 times but 32 times; a

slight increase in the diameter of a pipe gives, therefore, a very much greater proportional increase in discharge.

The table is capable of application to cases such as the determination of the diameters of two or more pipes where bifurcation takes place, where unequal or equal division of the supply is made from a main to separate districts, and when the conditions of rule (1) hold good, that is, if the hydraulic grade is the same; thus suppose a main pipe 44 inches in diameter is carrying 25·7 cubic feet of water in a minute of time, and there are two districts, one of which is to be supplied with 15·58 cubic feet, and the other with 9·85 cubic feet in a minute, it will be deduced from the first two columns that the diameter of the pipes to these two districts would require to be approximately 36 and 30 inches respectively. The figures in the other vertical columns show the number of pipes of the diameter indicated, which, under similar conditions of head and length, are required to give an equivalent discharge: thus 20·31 three-inch pipes would be required in place of one ten-inch, or 2·16 twenty-two-inch pipes in place of one thirty-inch pipe :—

Relative discharging Capacities of Full, Smooth Pipes.

Diameter in feet = d.	Relative discharging powers = $d, \frac{5}{2}$.	3	4	6	8	10	12	14	16	18	20	22	24	27	30	33	36	40	44	48	Diameter in inches.
4	32·000								15·59	11·61	8·92	7·03	5·65	4·21	3·24	2·55	2·05	1·58	1·24	1	48
3·677	25·750							17·50	12·54	9·34	7·17	5·66	4·55	3·39	2·61	2·00	1·65	1·27	1		44
3·333	20·235						20·23	13·47	9·85	7·34	5·64	4·44	3·57	2·66	2·05	1·65	1·26	1			40
3	15·588						15·58	8·41	7·59	5·65	4·34	3·42	2·74	2·05	1·58	1·24	1				36
2·750	12·541				34·55	19·78	12·54	8·52	6·11	4·55	3·49	2·75	2·21	1·65	1·27	1					33
2·500	9·859				27·09	15·54	9·85	6·54	4·80	3·57	2·74	2·16	1·74	1·29	1						30
2·250	7·594			42·95	16·61	9·96	7·59	5·16	3·70	2·75	2·11	1·67	1·34	1							27
2	5·657			32·00	15·58	8·92	5·65	3·84	2·75	2·05	1·57	1·24	1								24
1·833	4·549		70·96	25·73	12·53	7·17	4·55	3·09	2·16	1·65	1·26	1									22
1·667	3·588		55·96	20·29	9·88	5·66	3·58	2·43	1·74	1·30	1										20
1·500	2·756		42·01	15·58	7·25	4·34	2·75	1·87	1·34	1											18
1·333	2·052	65·77	32·01	11·60	5·65	3·23	2·05	1·39	1												16
1·167	1·471	47·14	22·94	8·32	4·05	2·32	1·47	1													14
1	1	32·05	15·60	5·65	2·75	1·57	1														12
.8333	·6339	20·31	9·88	3·58	1·74	1															10
.6667	·3629	11·63	5·66	2·05	1																
·5000	·1768	5·66	2·75	1																	6
·3333	·0641	2·05	1																		4
·2500	·0312	1																			3

Sizes of pipes ordinarily manufactured.—Pipes of certain diameters such as 11″, 13″, 17″, 19″, 23″ are seldom cast and above 24″ diameter it is usual to advance the diameters of pipes by 3″ at a time. The question is one of expense, if a pipe, say, 23″ is wanted, the question is whether it will be cheaper to take the 24″ pipes or call upon the maker to supply 23″ pipes, for the manufacture of which special boxes, moulds and other apparatus would be required. Pipes of diameters in ordinary use are very much cheaper than any special sizes ordered and a long length of one size of pipes is cheaper per ton than the same tonnage of mixed sizes. The cost of the pipe in the ground is, however, what has to be considered and with heavy freight charges there is great economy in having various sizes of pipes transported together, as they pack inside one another and the freight rate is usually one of space (40 to 50 cubic feet per ton) and not of actual weight.

Pumping mains.—Some remarks in regard to pumping mains are necessary. These require special principles to be applied to them when fixing their diameters. For all practical purposes, about one-half the velocities tabulated on page 342 *ante* may be taken as the most economical velocities through pumping mains. It is to be observed that, if through the same size of pipe, an increased quantity has to be pumped, the velocities will be proportionally increased, but the height to which it must be pumped or rather the increased pressure will be proportional to the square of that velocity.

Referring to the following diagram :—



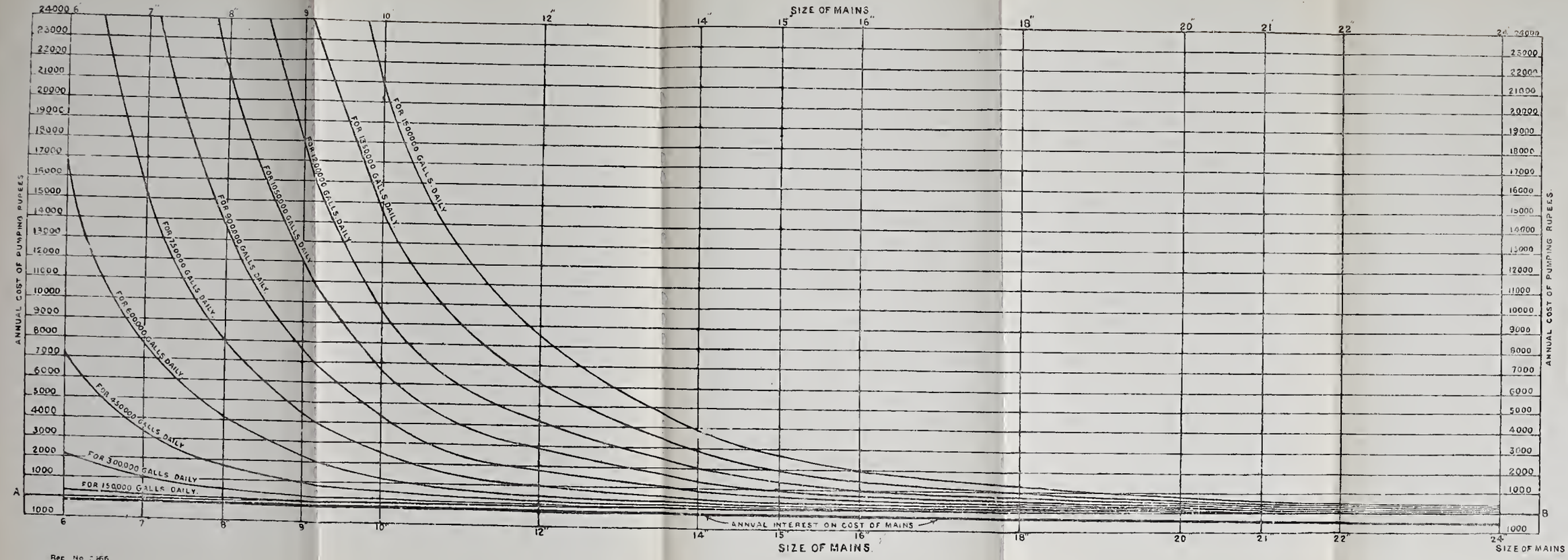
let P be the pumping station and TT represent the site of the town to be supplied; the water has to be raised to a height X above T, and this requires a pressure to be put on which will cause the water to rise not only to a height X above T, but to an additional height (h) which is the loss of head between the pumping station and the town. The height (h) may be varied; if decreased the main will require to be larger, if increased, smaller; in the former case the cost of pumping will be less, but cost of the main will be greater;

in the latter, the cost of pumping will be more but the cost of the main less. The question, therefore, is what is the most economical size of main; that size is the most economical when the annual cost of pumping plus the annual cost (or interest on cost as money is usually borrowed for water works) of the main is the least possible. The annual cost of pumping ought to include (1) interest on cost of engines and pumps, (2) on the buildings and (3) cost of fuel. The annual cost of the main will be the interest paid on the first cost of the main plus the cost of laying, and cost of repairs, (these latter are easily determined) but until the size of the engine has been fixed the cost of pumping cannot exactly be determined, nor can the cost of the buildings, &c., be accurately fixed. For all practical purposes, as the limits within which the size of the mains lie and the head h, are usually, in comparison to the total lift, comparatively small, and the HP of the engine will thus not vary to any very great extent, it suffices to consider in the first instance merely the annual cost of fuel as representing the cost of pumping (this will vary directly with the lift h) the larger and remaining portion of the lift being the same in any circumstances and the size of the main is not dependent on it; therefore if it is determined that the cost of fuel for pumping through a certain size of main plus the annual cost (or amount of interest on cost) of such main is the least possible, that size of main may be taken as the most economical.

The cost of fuel, staff, repairs, &c., is so very different in one place from another and at one time and another, and so similarly the cost of pipes, and therefore the annual interest on first cost of mains, that the most economical combination cannot be determined by empirical formulæ.

A graphic method of arriving at the economical combination is by plotting curves shewing the annual cost of pumping, and, at the same time, plotting a curve shewing the annual interest on cost of mains of various diameters. This method is illustrated on the plate accompanying, where the cost of pumping is taken at 10 annas per million gallons per foot high, and the annual interest at 4 per cent. on cost of the mains as laid at Rs. 125 á ton. Along an abscissa AB in the diagram, distances proportioned to the several diameters of the pipes are set off and from each of these points, ordinates are drawn to any convenient scale representing the annual cost of pumping through any particular length of main (say 1,000 feet) based on the loss of head required to ensure the determined discharge through that particular diameter of pipe and from the same points ordinates in length

DIAGRAM FOR DETERMINATION OF MOST ECONOMICAL SIZE OF PUMPING MAIN



Ref. No. 1366
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Photo-Zinco., Survey Office, Madras.
1896

representing the annual interest on first cost of the same length of each size of main are drawn below the line A B. Curves are then drawn through the points so obtained; if a vertical line be drawn at the point where the curves most closely approach each other, between the two curves representing, respectively, the cost of pumping and the annual interest on cost of mains, the point where that line crosses the horizontal line shews the size of main which is the most economical.

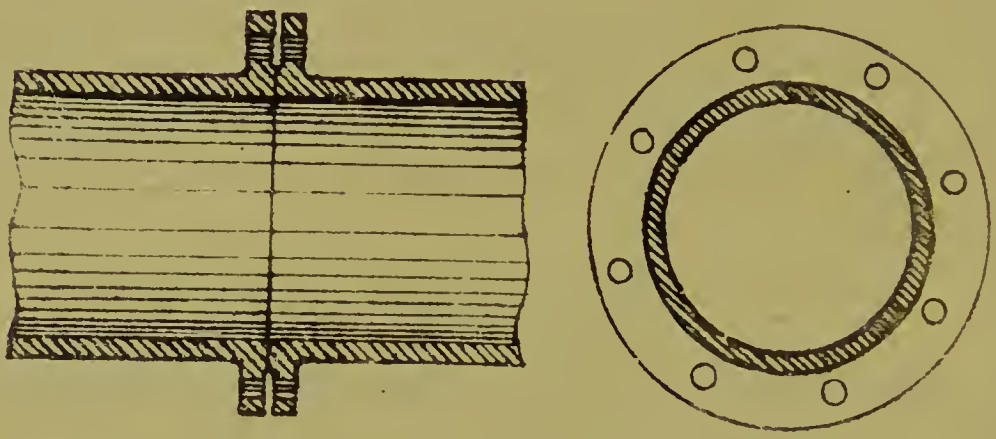
In determining the annual cost of pumping the lift (h) to be considered is not that due to the average daily consumption per minute, but to the maximum consumption; for example in the diagram the pumping charges for 150,000 gallons per day are calculated for the head (per 1,000 feet) due to $\frac{150{,}000 \text{ gallons daily}}{12 \times 60 \text{ minutes}}$ or 208·3 gallons per minute on the assumption that one half the supply per head is delivered in six hours.

DETAILS OF PIPES AND APPLIANCES USED IN WATER-SUPPLY WORKS.

Materials used in the construction of pipes.—The ordinary material used for the construction of pipes for water-supply works is cast iron; in small works, where the head on the pipe can be limited to from 5 to 10 feet, stoneware or cement pipes may be used; where these pipes can be laid near to the level of the hydraulic gradient, they are very suitable and save considerable expense. Cast iron, however, is the material generally employed, that is, for street mains and branches. House service pipes, pipes feeding fountains (or what are known as 'fountains' in India), branches to stand pipes when below $2\frac{1}{2}$ inches diameter are of lead or wrought iron; this latter material is coming more and more into use displacing lead. In Southern India wrought-iron pipes are used in all such cases. Riveted steel pipes are also used for mains especially for those of large diameter; these pipes are very light, easily handled, can be made in longer lengths than cast iron pipes and can be easily laid and perfectly jointed. They are used with advantage where a pipe has to be laid under water (this is due to their extreme lightness). Where freights are heavy, transport difficult, and roads bad or where proper appliances for moving heavy objects are not available, steel pipes are to be preferred. Their cost is more than that of cast iron pipes; though their weight is very much less, this fact does not usually reduce their cost below that of cast iron pipes of the same size at the place of production; sometimes,

however, the cost of freight, dues and transport charges (especially if pipes of varying diameter are used and can be 'nested' for transport) will be such that steel pipes can be *delivered* at the site of the works at a less cost per foot than cast iron pipes.

Joints of pipes.—Cast iron pipes are connected together by flanged joints or spigot and faucet joints; the latter class of joint is subdivided into 'plain' (S and F) and 'turned and bored' (T and B) joints. The diagram opposite gives sections of turned and bored and spigot and faucet joints. A flanged joint pipe is shown below:—



Flanged pipes are not used to any extent on water works except in special positions. Flanged joints are ordinarily 'faced,' that is, their surfaces which come into contact are accurately planed. The joint is made water-tight by the insertion, between the flanges, of yarn and lead, India rubber, asbestos or soft lead rings; these are compressed when the joints are screwed up tight. Flanged pipes can be easily taken out of a line of pipes, but they do not allow for expansion and contraction, and the joints are expensive to make. Spigot and faucet joints are therefore usual on water-supply mains. In turned and bored joints a *portion* of the outside of the spigot end of the pipe is accurately turned, and the inside of the faucet end similarly bored, so that when one pipe is thrust into each other the joint is water-tight. The remaining portion of the joints of turned and bored pipes is sometimes filled with cement mortar. With plain spigot and faucet joints, lead is run into the joint after yarn has been well rammed home.

The following specification includes the conditions which should be observed in the manufacture of cast iron pipes. It is the one in use in the author's department in Madras, and has been found to meet all requirements:—

Turned and Bored Pipes

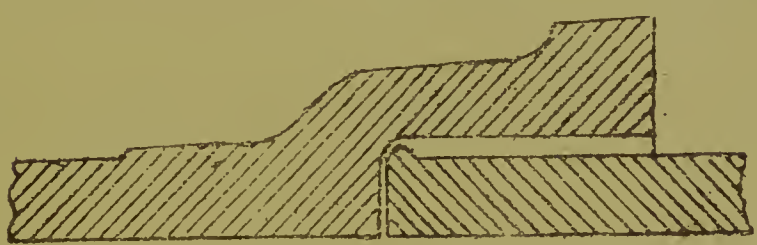


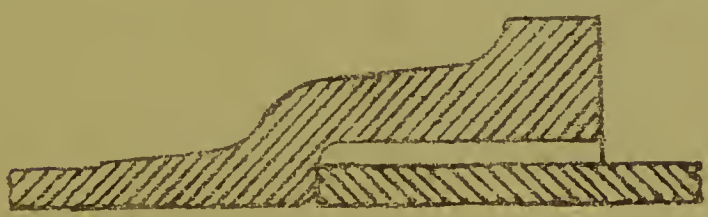


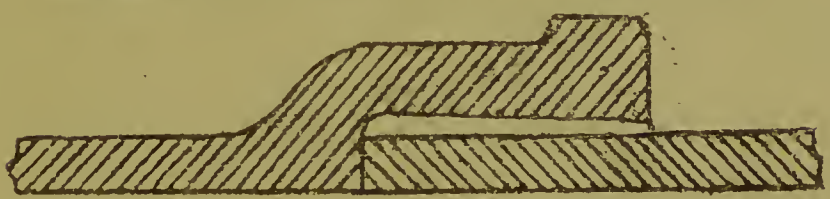


Plain Pipes











SPECIFICATION FOR CAST IRON PIPES, SPECIALS, SLUICE VALVES, AIR VALVES, HYDRANTS, FOUNTAINS, &c., TO BE SUPPLIED TO THE MUNICIPAL COUNCIL OF . . . . .

The pipes required consist of the quantities and sizes as set forth in the schedule accompanying this specification. The quantities and sizes of pipes, specials, valves, &c., mentioned are believed to be the quantities and sizes required. But the Engineer shall nevertheless have the power to vary, extend or diminish the stated quantities, diameters or thickness of the pipes and specials, provided that the gross weight of such pipes and specials or in respect to valves, fountains, &c., the gross quantity of each size, be not increased or diminished by such alteration more than 20 per cent. as occasion may require from time to time. The pipes shall be made in accordance with the standard drawings which will be furnished on application. The permitted deviation in weight for each size of pipe is that noted in the schedules, but the total weight of pipes to be paid for shall not exceed the total scheduled weight by more than 1 per cent.

2. Eighty per cent. of each class and size of pipe shall have turned and bored joints and twenty per cent. shall have ordinary spigot and faucet joints.

3. All bends and branches and other specials shall have plain spigot and faucet joints. They shall be formed in accordance with the requirements noted on the standard drawings.

4. Each pipe and special shall have cast on it the letters M.C. in Roman characters $1\frac{1}{2}$ inches long and $\frac{1}{8}$ inch projection and the diameter of each pipe and special shall also similarly be cast beneath such letters. Numbers consecutive for each lot of pipes and specials of the same diameter shall be marked conspicuously on the pipes before delivery; the weight of each pipe and special above 5 inches in diameter shall be marked on it; such numbers and figures shall be in white paint. All branch pipes shall have their sizes marked thus—8 in. × 6 in.; taper pipes shall be similarly marked. Bends shall be marked $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, or $\frac{1}{32}$ as the case may be.

5. Straight pipes 4 inches and above in diameter shall be cast vertically in dry sand moulds, but pipes 3 inches and below in diameter may be cast on declivity in green sand. All pipes shall be cast without the use of core nails, thickness pieces, or any substitute therefor.

6. The metal shall be from mine pig without admixture of cinder iron or other inferior material and shall be stout, tough and close grained and of such strength that a bar 1 inch square and 38 inches long weighing not more than 10 lb. when supported at points 36 inches apart and loaded in the middle shall sustain a weight of not less than 700 lb.

7. The pipes and specials shall be free from scoriæ, sand holes, air bubbles and all other imperfections. They shall be truly cylindrical in bore, smooth within and without and shall have their inner and outer surfaces truly concentric. They shall be perfectly fettled and cleansed, so that no humps or rough places shall be left in the barrels or sockets, and the runners shall be carefully cut off so as to preserve a square angle on the inner edge of the sockets against which the joint is to be made; and to ascertain and ensure that the sockets will, in all cases, receive the spigots, and that the spigots will, in all cases, enter into the bottom of the sockets, a circular iron template of proper dimensions shall be passed to the bottom of every socket and a circular ring of proper dimensions shall be passed over every spigot. The taper of the turned and bored portion of the pipes shall be 1/32nd part of an inch for each inch of its length. To ensure these conditions it is required that a large proportion of the pipes shall be put together with iron wedges of sizes representing the proper thickness of the joint as shown on drawings annexed to this specification.

8. The pipes shall be carefully coated externally and internally with coal, pitch and oil, according to Dr. K. Angus Smith's process, the composition to be applied at proper heat and as soon as possible after the pipes are cast and before any rust sets in.

9. The pipes shall be tested by a hydrostatic pressure of 130 lb. on the square inch equal to a column of water 300 feet in height and whilst subject to such pressure shall be struck from end to end with a hammer from 5 to 7 lb. in weight according to the size and strength of the casting. The testing of the pipes and special castings is to be done by the contractor at the foundry at his expense under the inspection of a person to be appointed by the Engineer. Further, the pipes, after being laid and jointed in their several positions and while uncovered, shall, from time to time, be tested in such lengths, and at such pressures not exceeding

the actual working pressure due to the head of water by more than 50 per cent. as the Engineer may consider advisable.

10. All pipes wherever any sand or air holes may be found plugged up or otherwise shall be rejected.

11. The curved pipes and other special castings shall be executed accurately according to the standard drawings, dimensions and tables which will be furnished to the contractor by the Engineer. They must not be made of greater thickness than the straight pipes, and every care must be taken to ensure that these pipes shall properly join with the straight pipes and other castings with which they may be intended to connect by actually placing such pipes in proper connection with standard straight pipes of a like diameter.

* 12. The pipes shall be conveyed to, and delivered by, and at the expense of, the contractor at the ..... Railway station, when they will be taken charge of; until then they shall be at the contractor's risk.

13. The sluice valves to be supplied shall be of the sizes mentioned in the schedule; the valves shall be of a pattern similar to those shown on standard drawings or to the designs shown in the catalogues of one of the following firms, viz.:—

Glenfield Iron Company, Kilmarnock; Stone and Co., Deptford; Beck and Co., London; Laidlaw and Sons, Glasgow.

14. They shall be double-faced gun metal valves, both faces being accurately scraped to a bearing and shall be proved to a head of 600 feet of water. They shall be of the best materials and workmanship. One valve key shall be provided for each ten valves. The heads of the valve spindles shall be arranged so that at most not more than two or three different sizes of keys in all will be required. Each valve shall have one spigot and one faucet tail piece with flanges to be bolted on; the spigot and faucet ends shall be made in accordance with the dimensions shown on the standard drawings for cast-iron pipes. The tail pieces shall be supplied with 10 per cent. of bolts in excess of the number

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* NOTE.—*For the information of tenderers it may be stated that..... is .....miles distant viâ..... .....Railway from the nearest port of..... and.....miles from the port of..... ..... The average rate there for landing and loading pipes, &c., per ton is about Rs..... The Railway charges are.....pies per ton per mile or at owner's risk...annas per truck (.....) per mile; these rates are not guaranteed.*

actually required to bolt the valves and tail pieces together. For each valve there shall be a cover of one of the patterns shown on standard drawings; the numbers and patterns are detailed in the schedules.

15. The air valves shall be shielded automatic air valves. They shall be such as to contain balls of the sizes noted in the schedule. Air valves shall have surface boxes in numbers noted in schedule and as shown on standard drawings. For each $1\frac{3}{4}$ inches air valve shall be provided a $1\frac{1}{4}$ inches diameter stop ferrule (Glenfield Pattern), for screwing into the main.

16. All stop ferrules scheduled shall be similar to the above and have outlets screwed for wrought-iron pipes, and shall be of the sizes noted and shall be loose valve screwed down angle stop valve ferrules with loose dome shaped cover accompanying.

17. Hydrants shall be Tylor and Sons diaphragm hydrants or other previously approved pattern screwed brigade gauge. The hydrant cover shall be fixed on to the hydrant itself. For use on the hydrants single outlet copper stand pipes are required. The stand pipes at their lower ends shall be screwed to fit hydrants; they shall have revolving elbows which elbows shall be similarly screwed to brigade gauge. Each stand pipe shall have ten feet of hose $2\frac{1}{2}$ inches diameter with one brass male half coupling to fit hydrants and stand pipes. The inside diameter of the hydrant discharge pipe, and of the copper stand pipes and hose shall be $2\frac{1}{2}$ inches.

18. The fountains shall be Pillar or Wall Tap fountains of the patterns and designs shown on the standard drawings.

19. The Pillar fountains shall each have two taps. Each fountain shall be accompanied by—

5 feet of 2″ wrought-iron pipe, galvanized (vertical length);
30 feet of 2″ wrought-iron pipe, galvanized (horizontal length);
2 wrought-iron elbows, 2-inch, galvanized;
4 do. do. 2-inch couplings do.
1 cast-iron grating, 1′ 6″ × 9″ × 1″ as shown on standard drawings.

20. Each single Wall Tap fountain, Glenfield Pattern, shall be accompanied by—

5 feet of 2″ wrought-iron pipe, galvanized (vertical length);
30 feet of 2″ wrought-iron pipe, galvanized (horizontal length);
3 wrought-iron elbows, 2-inch galvanized;
1 do. knee, 2″ × 1¼″ do.
4 do. 2-inch couplings, galvanized;
1 cast-iron grating, 1′ 6″ × 15″ × 1″ as shown on standard drawings.

21. For each double Wall Tap fountain (2 Wall Taps, Glenfield Pattern) in addition to what is required to be supplied for a single Wall Tap, the undernoted shall be supplied:—

1 wrought-iron T(2″ × 1¼″ × 1¼″), galvanized;
2 wrought-iron elbows, (1¼″ diameter), galvanized;
14 feet of wrought-iron piping (1¼″ diameter), galvanized.

22. The extra items specified in clauses Nos. 19 to 21 are not separately entered in the schedules; they are included in the items 'Fountains complete.'

23. Spare rubber rings and plugs sufficient for two years' consumption shall be supplied with each fountain and hydrant. The contractor in making his tender for valves, hydrants, fountains, &c., shall enter such rates in the schedule as will include the cost of all necessary accessories which are not specifically detailed in the schedule.

24. Smaller articles such as Wall Tap fountains, small valves, stop cocks, wrought-iron bends, elbows, bolts, &c., shall be carefully packed in numbered cases and boxes. Larger articles may be sent in the manner most convenient to the contractor. All articles shall be delivered by the contractor or his agent (to whom the bills of lading and other documents should be sent) to an agent to be appointed by the Engineer at the ..... station of the ..... Railway. Each article shall be numbered and each case shall have its contents described on the outside of the case. Until the time of delivery and until the cases have been opened and inspected and approved of (and this shall be done within a reasonable period after delivery) the articles shall be at the risk of the contractor.

25. Nevertheless the Engineer shall be entitled to instruct an agent to inspect the articles either during or immediately after manufacture and the agent may then and there reject any articles which he considers do not comply with this specification, but the fact of his not rejecting any articles shall not absolve the contractor from risk or liability as the articles will be finally accepted only upon delivery at ....

26. Delivery by the contractor shall be made of the whole materials within .... of date of acceptance of tender.

27. In case the Engineer shall have reasonable grounds to suppose that the contractor has not used due diligence in making and delivering such pipes and special castings, valves, fountains, hydrants, &c., or any of them, it shall be in the power of the Engineer to order and purchase the same or any substitute for the same elsewhere, and to deduct or cause to be deducted any extra charges thereby incurred from any sum or sums of money which may then be or may afterwards become due or owing to the said contractor and any pipes so ordered or purchased shall be considered to form part of the number to be supplied by the said contractor; and in the event of the amount of the contract sum not being sufficient in such case to complete the work in the manner and under the conditions described in this specification, and also to meet the liabilities which may have been incurred under the contract or in case the council or others to whom they may be responsible, sustain any loss or damage from the work not being completed within the time agreed, or otherwise from the non-fulfilment of the contract, then the contractor shall indemnify the council or the said persons sustaining injury from such loss or damage.

28. The contractor shall be entitled to payment of his work in the following manner, that is to say, to an instalment amounting to 90 per cent. of the value of pipes, valves, castings, fountains, &c., accepted within two months of delivery and acceptance and to the balance arising from such contract within three months of the date of the completion of such contract. Payment as above will be made in India by the Egineer to the contractor or his agent or in England by the Engineer's agents within.....months of a notification of delivery and value of acceptance. This notification will usually be sent by telegram. Provided always that the said Engineer or the Assistant Engineer, who may be in charge of the works, shall have power to reject all or any of such pipes,

valves, hydrants, fountains, &c., in the event of the same being in his judgment of inferior quality or otherwise or not in conformity with this specification or the drawings, and provided also that such instalments or balances or any portion thereof respectively shall not be considered to be due or owing to the said contractor unless and until seven days after the said Engineer or Assistant Engineer shall have given his certificate in writing that the said contractor is reasonably entitled thereto, but nevertheless such certificate shall only be deemed to authorize a payment on general account, subject to, and pending, the future complete fulfilment by the said contractor of the terms and conditions of the specification, and of the contract founded thereon.

29. Further, and also in event of the failure of any of the pipes, valves, fountains, hydrants, &c., within 12 months of their delivery, and if the failure should arise from any defect in their construction of which the Engineer shall be the sole judge, the contractor shall be held responsible for the damage and shall on demand refund to the Municipal Council any expense to which they have been subjected by reason of such failure.

Thickness of cast iron pipes.—The thickness, which cast iron pipes should have, is a question which has called forth many opinions and formulæ. If the pipes were made thick enough to resist only the maximum pressure they would ordinarily be subjected to, they would be so thin that they could not be safely handled. Again it is not possible to ensure that pipes shall be exactly of the same thickness throughout. But pipes, in addition to the maximum pressure due to the head on the pipe, have to withstand shocks due to water being sharply shut off. This is called 'ramming'; of course precautions are taken (especially on pumping mains) by providing relief valves, &c., to ensure that this is not excessive, though it cannot altogether be prevented.

The following formulæ for the thickness of pipes have been proposed:—

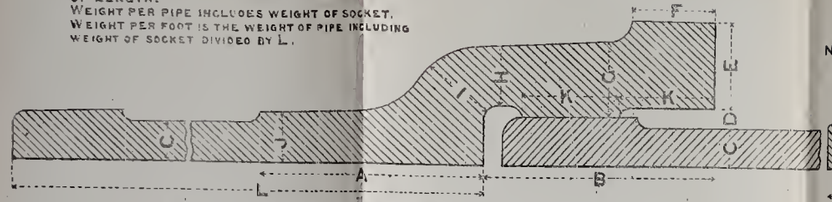
By Molesworth—

$$t = \cdot 00125\ Pd + x$$

$$\begin{cases} x = \cdot 37 \text{ inch for pipes below 12 inches in diameter.} \\ = \cdot 5 \text{ inch for pipes from 12 inches to 30 inches in diameter} \\ = \cdot 6 \text{ inch for pipes from 30 inches to 50 inches in diameter.} \end{cases}$$

TURNED AND BORED PIPES

NOTE – TAPER OF BORED PORTION $\frac{1}{32}$ INCH PER INCH OF LENGTH.
WEIGHT PER PIPE INCLUDES WEIGHT OF SOCKET.
WEIGHT PER FOOT IS THE WEIGHT OF PIPE INCLUDING WEIGHT OF SOCKET DIVIDED BY L.



DIMENSIONS AND WEIGHTS OF CLASS A PIPES.

BORE OF PIPE INCHES	A	B	C	D	E	F	G	H	I	J	K	L	WEIGHT PER PIPE CWT.	WEIGHT PER PIPE QRS.	WEIGHT PER PIPE LBS.	WEIGHT PER FOOT RUN CWT.	BORE OF PIPE INCHES
	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES						
2	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	6	0	2	4	·089	2
2½	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	6	0	2	17	·107	2½
3	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	1	0	10	·121	3
4	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	1	1	20	·156	4
5	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	2	0	7	·229	5
6	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	2	1	27	·277	6
7	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	3	1	1	·362	7
8	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	3	2	23	·412	8
9	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	4	2	24	·524	9
10	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	5	0	16	·571	10
12	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	6	3	13	·76	12
14	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	11	3	0	·980	14
15	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	12	1	12	1·03	15
16	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	14	1	17	1·19	16
18	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	16	0	9	1·34	16
20	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	19	1	8	1·61	20
21	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	20	0	18	1·68	21
22	5	5	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	22	3	6	1·90	22
24	5	5	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	24	3	11	2·07	24

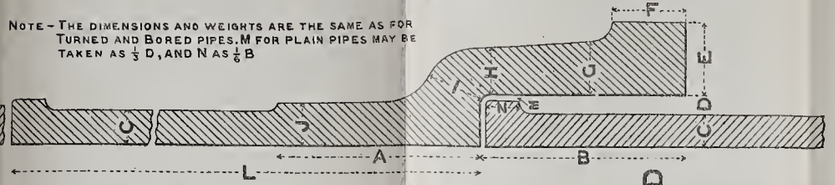
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DIMENSIONS AND WEIGHTS OF CAST IRON PIPES AND SPECIALS

FOR BRANCHES, SADDLES, COLLARS & C. VIDE SUCCEEDING PLATE

PLAIN PIPES

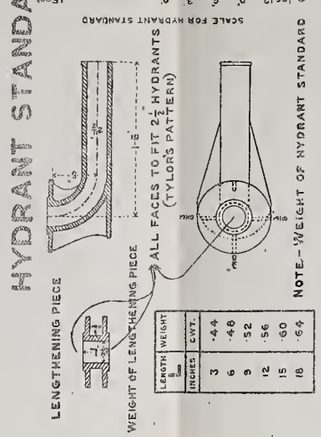
NOTE – THE DIMENSIONS AND WEIGHTS ARE THE SAME AS FOR TURNED AND BORED PIPES. M FOR PLAIN PIPES MAY BE TAKEN AS $\frac{1}{3}$ D, AND N AS $\frac{1}{6}$ B



DIMENSIONS AND WEIGHTS OF CLASS B PIPES

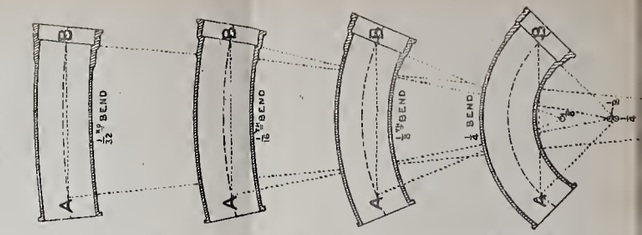
BORE OF PIPE INCHES	A	B	C	D	E	F	G	H	I	J	K	L	WEIGHT PER PIPE CWT.	WEIGHT PER PIPE QRS.	WEIGHT PER PIPE LBS.	WEIGHT PER FOOT RUN CWT.	BORE OF PIPE INCHES
	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES					
2	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	6	0	2	4	·089	2
2½	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	6	0	2	17	·107	2½
3	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	1	0	10	·121	3
4	3	3	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	1	1	20	·156	4
5	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	1	3	14	·208	5
6	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	2	1	0	·250	6
7	3½	3½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	2	3	12	·317	7
8	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	3	1	7	·366	8
9	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	4	0	18	·462	9
10	4	4	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	4	2	22	·511	10
12	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	9	6	0	26	·690	12
14	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	10	2	14	·885	14
15	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	11	1	0	·938	15
16	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	12	0	0	1·000	16
18	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	15	0	0	1·250	18
20	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	17	3	2	1·48	20
21	4½	4½	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	18	2	12	1·55	21
22	5	5	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	21	0	14	1·76	22
24	5	5	3⅛	1-11/32	7/8	1	5/16	5/16	3/4	1/2	1/4	12	23	0	5	1·92	24

HYDRANT STANDARD



NOTE – WEIGHT OF HYDRANT STANDARD 07.5 CWTS

BENDS



DIMENSIONS AND WEIGHTS OF BENDS

BORE OF PIPE	LENGTH OF CHORD A.B FOR BENDS OF ALL ANGLES	RADIUS O.A OR O.B OF BENDS 1/4	1/8	1/16	1/32	LENGTH OF ARC A.B OF BENDS 1/4	1/8	1/16	1/32	WEIGHT OF BENDS 1/4	1/8	1/16	1/32	BORE OF PIPE
INCHES	FEET	FEET	FEET	FEET	FEET	FEET	FEET	FEET	FEET	CWT.	CWT.	CWT.	CWT.	INCHES
2	1·50	1·06	1·36	3·84	7·65	1·67	1·54	1·51	1·50	·51	·37	·31	·28	2
2½	1·50	1·06	1·56	3·84	7·65	1·67	1·54	1·51	1·50	·62	·46	·38	·34	2½
3	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	·69	·50	·44	·41	3
4	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	·82	·69	·57	·53	4
5	1·50	1·06	1·96	3·84	7·65	1·67	1·54	1·51	1·50	1·08	·88	·75	·66	5
6	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	1·32	1·19	1·03	·95	6
7	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	1·75	1·50	1·38	1·32	7
8	2·00	1·41	2·61	5·13	10·20	2·22	2·05	2·02	2·00	1·98	1·73	1·57	1·49	8
9	2·50	1·77	3·27	6·41	12·75	2·78	2·56	2·52	2·50	2·80	2·52	2·19	2·03	9
10	2·50	1·77	3·27	6·41	12·75	2·78	2·56	2·52	2·50	3·10	2·76	2·50	2·38	10
12	3·00	2·12	3·92	7·69	15·30	3·33	3·06	3·02	3·00	4·54	3·70	3·37	3·49	12
14	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	5·28	4·31	4·21	4·15	14
15	3·00	2·12	3·52	7·69	15·20	3·33	3·08	3·02	3·00	5·80	5·32	4·98	4·81	15
16	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	6·05	5·50	5·26	5·00	16
18	3·00	2·12	3·92	7·69	15·30	3·33	3·08	3·02	3·00	7·50	6·25	6·18	6·13	18
20	4·00	2·83	5·23	10·25	20·41	4·44	4·10	4·03	4·01	9·59	9·50	9·19	9·16	20
21	4·00	2·83	5·23	10·25	20·41	4·44	4·10	4·03	4·01	10·50	10·25	9·50	9·43	21
22	4·00	2·83	5·23	10·25	20·41	4·44	4·10	4·03	4·01	11·81	10·74	10·00	9·56	22
24	4·00	2·83	5·23	10·25	20·41	4·44	4·10	4·03	4·01	12·83	11·69	11·40	11·20	24

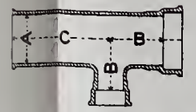
NOTE – DIMENSIONS OF SPIGOT AND SOCKET WILL BE SAME AS FOR ORDINARY PIPES.

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1896

BRANCH PIPES

DIMENSIONS AND WEIGHTS OF SPECIALS

FOR STRAIGHT PIPES, SEE PROVIDE PRECEDING PLATE.

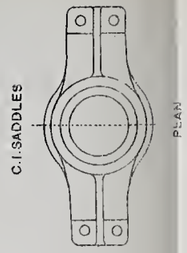


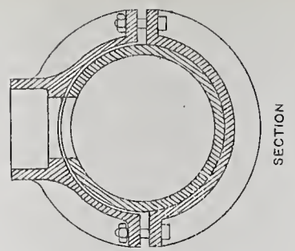
DIMENSIONS AND WEIGHTS OF BRANCH PIPES

DIAM. A	LENGTH B	LENGTH C	SIZE OF BORE OF DROP PIECES IN INCHES. 2	2½	3	4	5	6	7	8	9	10	12	14	15	16	18	20	21	22	24	DIAM. A
INCHES	INCHES	INCHES	WEIGHT IN CWTS:																			INCHES
2	5	12	·34																			2
2½	5½	12½	·35	·42																		2½
3	5¾	13½	·45	·48	·50																	3
4	6½	15	·58	·61	·63	·68																4
5	7¼	16½	·89	·92	·94	·99	1·06															5
6	8	18	1·12	1·16	1·18	1·23	1·30	1·37														6
7	8¾	19½	1·45	1·48	1·50	1·55	1·62	1·69	1·83													7
8	9½	21	1·70	1·73	1·75	1·80	1·87	1·92	2·08	2·15												8
9	10¼	22½	2·22	2·25	2·27	2·32	2·39	2·46	2·60	2·67	2·82											9
10	11	24	2·58	2·61	2·63	2·68	2·75	2·82	2·96	3·03	3·18	3·26										10
12	12½	27	3·68	3·71	3·73	3·78	3·85	3·92	4·06	4·13	4·28	4·36	4·64									12
14	14	30	4·54	4·57	4·59	4·64	4·71	4·78	4·92	4·99	5·14	5·22	5·50	5·71								14
15	14¾	31½	5·43	5·46	5·48	5·53	5·60	5·67	5·81	5·88	6·03	6·11	6·35	6·60	6·84							15
16	15½	33	5·90	5·93	6·01	6·06	6·13	6·20	6·34	6·41	6·56	6·64	6·92	7·13	7·37	7·50						16
18	17	36	7·63	7·66	7·68	7·73	7·80	7·87	8·01	8·08	8·23	8·31	8·55	8·80	9·04	9·17	9·55					18
20	18½	39	9·67	9·70	9·72	9·77	9·84	9·91	10·05	10·12	10·27	10·35	10·63	10·84	11·08	11·21	11·63	12·10				20
21	19½	40½	10·32	10·35	10·37	10·42	10·49	10·56	10·70	10·77	10·92	11·00	11·28	11·45	11·73	11·86	12·28	12·75	12·90			21
22	20	42	11·95	12·02	12·04	12·09	12·16	12·23	12·37	12·44	12·59	12·67	12·95	13·16	13·40	13·53	13·95	14·42	14·57	14·96		22
24	21½	45	13·76	13·79	13·81	13·86	13·93	14·00	14·14	14·21	14·36	14·44	14·72	14·93	15·17	15·30	15·72	16·19	16·34	16·72	17·09	24

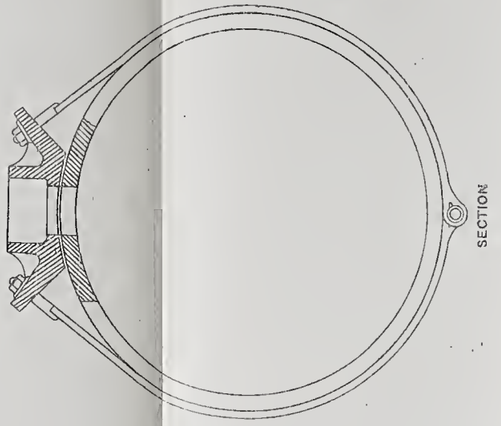
NOTE – DIMENSIONS OF SPIGOT AND SOCKET WILL BE SAME AS FOR ORDINARY PIPES.

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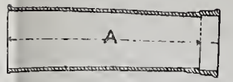








TAPER PIPES

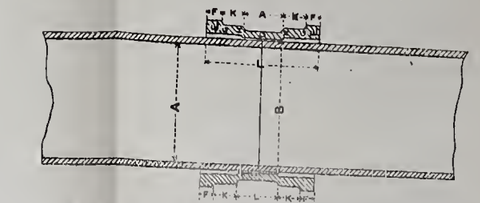


DIMENSIONS AND WEIGHTS OF TAPER PIPES.

SIZE	LENGTH A	WEIGHT
INCHES	FEET	CWT.
2½X2	2	35
3X2½	2	·49
4X3	2	·64
5X4	2	·83
6X5	2	·82
7X6	2	1·00
8X7	2	1·25
9X8	2	1·50
10X9	2	1·75
12X10	4	3·44
14X12	4	4·32
15X14	2	3·19
16X15	2	3·44
16X16	4	6·25
20X18	4	7·53
21X20	2	3·50
22X21	2	6·15
24X22	4	11·40

NOTE – DIMENSIONS OF SPIGOT AND SOCKET WILL BE SAME AS FOR ORDINARY PIPES.

COLLARS



DIMENSIONS AND WEIGHTS OF COLLARS

BORE OF PIPE A	LENGTH B	LENGTH C	LENGTH D	LENGTH E	LENGTH F	LENGTH G	LENGTH H	LENGTH I	LENGTH K	LENGTH L	WEIGHT	BORE OF PIPE A
INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	INCHES	CWT	INCHES
2	3	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	5	0·23	2
2½	3½	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	5	0·25	2½
3	4	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	5	0·32	3
4	5	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	5	0·43	4
5	6	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	5	0·53	5
6	7	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	10	0·53	5
7	8 1/8	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	10	0·64	6
8	9 1/8	3/8	1/4	7/8	1/2	11/16	5/8	3	2 1/4	10	0·75	7
9	10 1/4	3/8	1/4	7/8	1/2	11/16	5/8	3	3	11	0·96	8
10	11 1/4	3/8	1/4	7/8	1/2	11/16	5/8	3	3	11	1·19	9
12	13 3/8	3/8	1/4	7/8	1/2	11/16	5/8	4	3	12	1·25	10
14	15 1/4	3/8	1/4	7/8	1/2	11/16	5/8	4	3 1/4	12½	1·63	12
15	16 1/4	3/8	1/4	7/8	1/2	11/16	1	4	3 1/4	12½	2·00	14
16	17 3/8	3/8	1/4	7/8	1/2	11/16	1	4	3 3/16	13	3·00	15
18	19 5/8	11/16	1/4	1 1/8	1/2	1 1/16	1	4	3 3/16	13	3·75	16
20	21 1/2	3/4	1/4	1 1/8	1/2	1 1/16	1 1/16	4	3 1/4	13	4·00	18
21	22 3/4	3/4	1/4	1 1/8	1/2	1 1/16	1 1/16	6	3 3/16	15	4·98	20
22	23 7/8	13/16	1/4	1 1/8	1/2	1 1/16	1 1/16	6	3 1/2	15	5·19	21
24	25 7/8	13/16	1/4	1 1/8	1/2	1 1/4	1 1/8	6	3 3/16	16	6·50	22
									3 3/16	16	8·50	24

Photo-Zinco., Survey Office, Madras.
1896

By Rankine—

$$t = \sqrt{\cdot 0208 d}$$

By Fanning—

$$t = \frac{(P+100)d}{\cdot 4s} + \cdot 333\left(1 - \frac{d}{100}\right).$$

By Burton (modified) —

$$t = \frac{(P+100)\ d\ f}{2s} + \cdot 3$$

f=factor of safety adopted and may be equal to 4, as allowance is already made for ramming.

In all the formulæ—

t = thickness of metal in inches,

P = pressure in lb. per square inch,

d = internal diameter in inches,

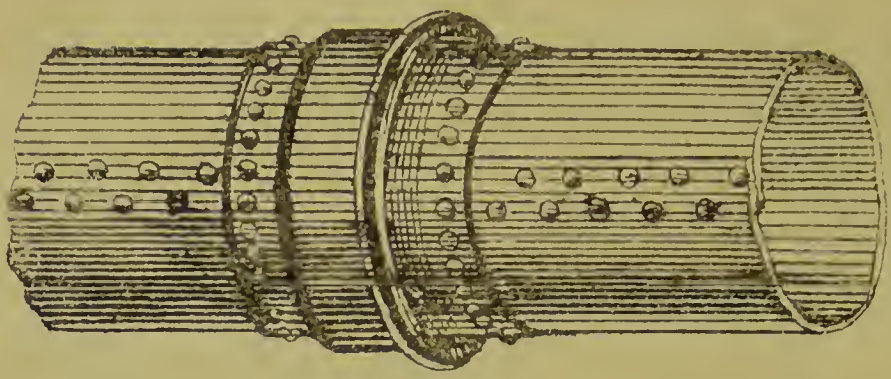
s = tensile strain of metal in lb. per square inch.

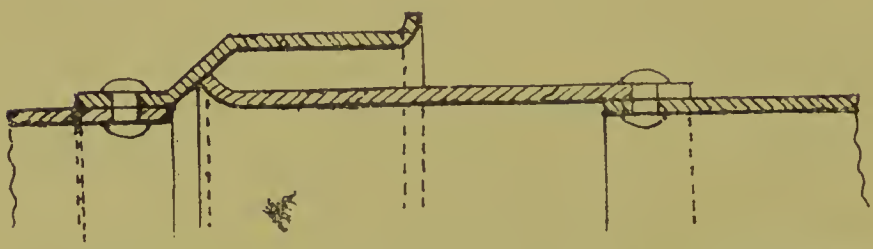
One formula is hardly to be recommended in preference to another, and unless under special conditions pipe-maker's catalogues are perhaps as good a guide as can be recommended, because they give the sizes and dimensions of pipes ordinarily made and used.

Dimensions and weights of cast iron pipes.—On the accompanying plates are shown the dimensions, weights, &c., of the pipes, bends and branches used in the author's department throughout the Madras Presidency. Class B pipes are ordinarily specified and are of sufficient strength, unless the pressures (that is including an allowance for ramming) are likely to exceed 250 feet. The weights include the weight of the socket end.*

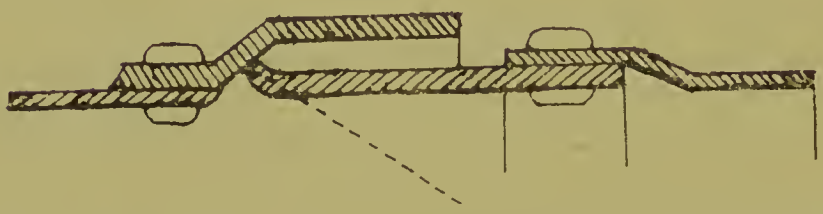
Steel pipes are more likely to rust than cast iron pipes and their thickness, being so very much less, their liability to burst is greater; it is said, however, that they will last as long as cast iron pipes which may become spongy or oxydised; under most conditions especially if a protective coating such as Dr. Angus Smith's composition has been thoroughly applied, experience goes to prove there is little danger or risk in using steel pipes. Sketches and sections of steel pipe joints are illustrated on the next page.

* The weight of a socket is usually taken as equal to a length of 1 foot of the pipe of which it forms a portion.

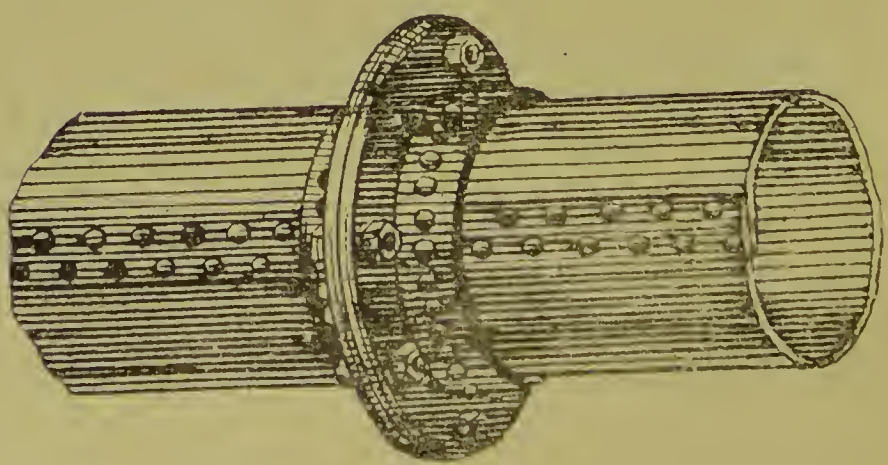




THE RILEY PATENT JOINT FOR WATER-PIPES.



THE DUNCAN PATENT JOINT FOR WATER-PIPES



THE FLANGED JOINT

The following table gives the standard gauges and thicknesses of riveted steel pipes as ordinarily manufactured with their prices :—

Pipes without joints—any lengths.

Internal diameter, inches.	9	10	11	12	13	14	15	16	17	18	19	20	21	24	27	30
Imperial wire gauge. ...	12	12	12	12	11	11	11	11	10	10	10	9	9	8	7	6
Equivalent in inches. ...	·104	·104	·104	·104	·116	·116	·116	·116	·128	·128	·128	·144	·144	·160	·176	·192
Price per foot of above gauge.	3/10	4/3	4/8	5/1	6/1	6/6	6/11	7/4	8/3	8/8	9/1	10/1	10/6	12/6	14/10	17/6
Price per foot of 1 extra gauge.	4/4	4/9	5/2	5/7	6/7	7/-	7/5	7/10	8/10	9/3	9/8	10/10	11/3	13/4	15/8	18/5
Price per foot of 2 extra gauges.	4/11	5/4	5/9	6/2	7/2	7/7	8/-	8/5	9/7	10/-	10/5	11/6	11/11	14/2	16/7	19/7
Price per foot of 3 extra gauges.	5/6	5/11	6/4	7/7	7/11	8/4	8/9	9/2	10/3	10/8	11/1	12/4	12/10	15/-	17/7	20/11
Price per foot of $\frac{3}{16}$ thick.	7/6	7/11	8/4	8/9	9/2	9/7	10/-	10/5	10/10	11/3	11/8	...	...	...	...	...
Price per foot of $\frac{1}{4}$ thick.	...	...	...	11/4	12/1	12/10	13/7	14/3	15/-	15/9	16/6	17/1	17/11	20/	21/11	23/9
Price per foot of $\frac{5}{16}$ thick.	...	...	...	...	...	...	16/3	17/1	17/10	18/9	19/7	20/5	21/3	23/9	26/3	28/9

The following table gives the prices in England of joints per pipe fitted on :—

Internal diameter, inches.	9	10	11	12	13	14	15	16
Riley Patent joint, each.	10/-	12/3	14/5	16/8	18/11	21/1	23/4	25/7
Converse do. do.	9/5	11/6	13/6	15/7	17/7	19/8	21/8	23/8
Steel sleeve do. do.	...	...	...	14/5	16/4	18/2	20/-	21/10
Flanged do. do.	11/1	13/10	16/8	19/3	22/2	25/-	27/9	30/6
Brown do. do.	11/1	13/1	15/-	16/11	18/10	20/10	22/9	24/8

Internal diameter, inches.	17	18	19	20	21	24	27	30
Riley Patent joint, each.	27/9	30/-	32/2	34/5	36/8	43/4	50/-	56/8
Converse do. do.	25/9	27/9	29/10	31/10	33/10	40/2	46/1	52/2
Steel sleeve do. do.	23/8	25/6	27/5	29/3	32/-	36/8	42/2	47/9
Flanged do. do.	33/4	36/1	38/10	41/8	44/5	52/9	61/1	69/5
Brown do. do.	26/8	28/7	30/6	32/6	34/5	40/3	46/1	51/11

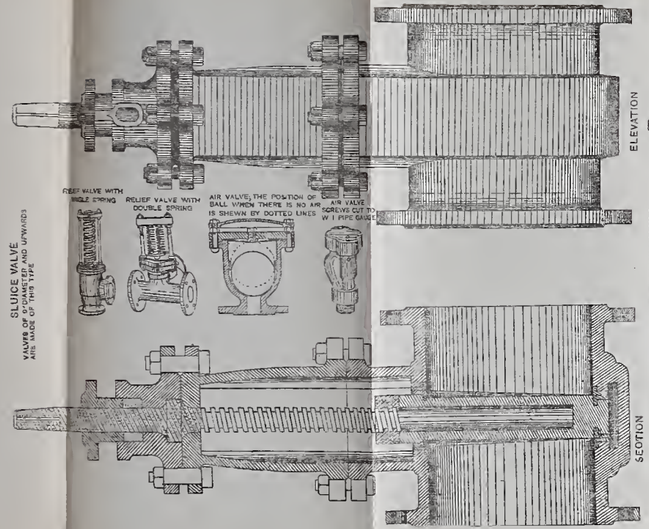
The prices of socket joints do not include lead and yarn for packing; but flanged joints are supplied complete, with bolts, nuts and rubber washers.

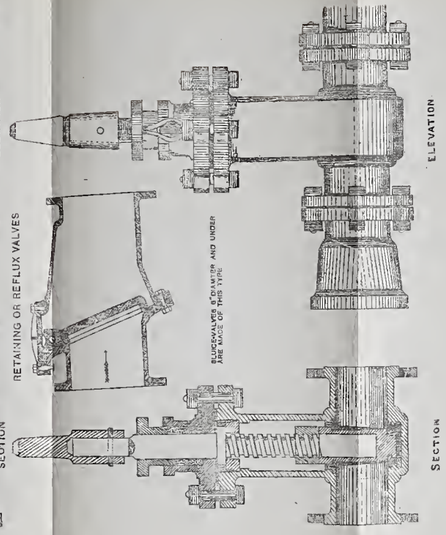
Intermediate diameters charged at next higher prices.

Intermediate thickness charged at next higher prices.

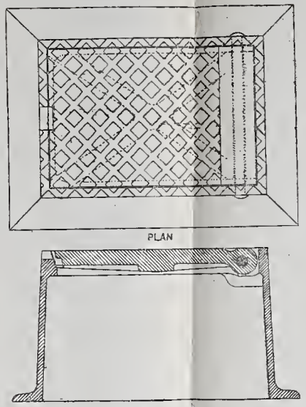
Service pipes.—Service pipes are those which convey the water from the street mains to the premises of the consumer. They may either be of lead or wrought iron; some waters have a solvent effect on lead and there is then a possibility of lead poisoning. But lead is so durable and so easily laid and handled that it is still the material commonly preferred in England for service pipes. In India where properly-trained plumbers are not available to any large extent, and probably not at all in many towns, wrought-iron pipes are to be preferred.

Weights of service pipes.—The following weights are those ordinarily prescribed for lead and wrought-iron pipes respectively :—

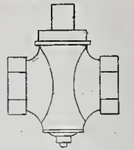


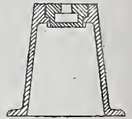


PIPE APPLIANCES

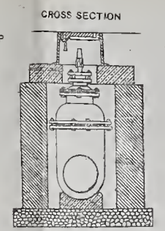


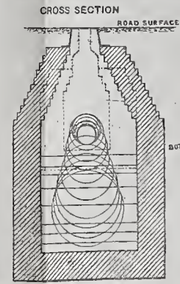


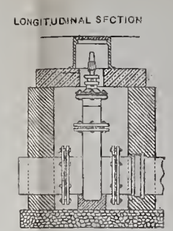


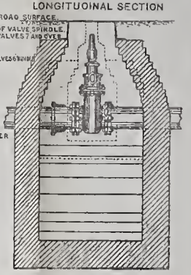


VALVE-PITS



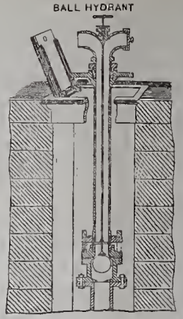


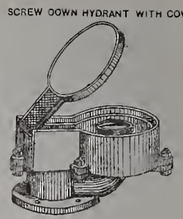


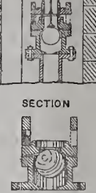


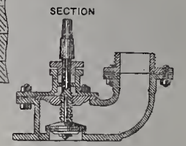
BOTTOMS OF PIT FOR VALVES 6 AND UNDER

Do.	7
Do.	8
Do.	9
Do.	10
Do.	12
Do.	14
Do.	15
Do.	16
Do.	18











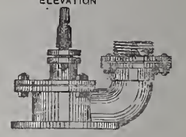


Photo-Zinco, Survey Office, Madras.

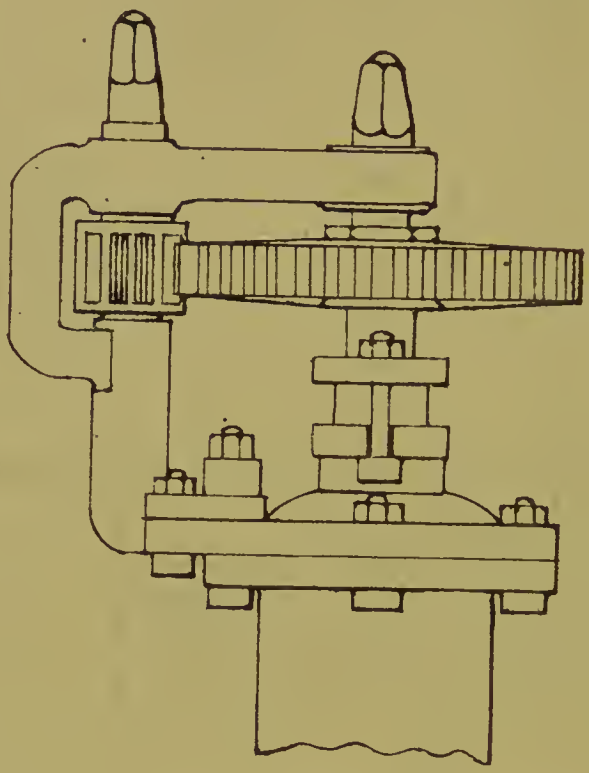
Lead pipes.				Remarks.
Diameter in inches.	Pressures 20 to 30 feet.	Pressure 50 feet.	Weight prescribed by the Metropolis Act 1871.	
⅛	4⅓	5⅓	6	The pressures given are a very small proportion of the actual bursting pressure, the factor of safety is very high.
¼	5⅓	7⅓	9	
1	8	9⅗	12	
1¼	11	13	16	
1½	14	17½	24	

Wrought-iron pipes.			
Diameter in inches.	Minimum weight, lb. per yard.	Diameter in inches.	Minimum weight, lb. per yard.
½	2·56	1½	8·83
¾	3·50	2	13·33
1	5·33	2½	19·77
1¼	7·50	3	27·50

Water works appliances.—The appliances used in water works consist of sluice valves, reflux valves, relief or safety valves, air valves, stand pipes, hydrants, stop cocks, ferrules, surface boxes, &c. All these are illustrated on the plates accompanying.

Sluice valves.—Sluice valves are the most common of the numerous appliances used in water works. The valve is simply a 'gate' (this is the American term) let down across the full bore of the pipe. When fully opened it leaves the bore of the pipe perfectly unobstructed. All sluice valves are now made approximately to the same pattern. Gun-metal faces for these valves are necessary, otherwise the valve might stick if left open or shut for any length of time. When valves

are of large size, they require to be opened and shut very slowly, and gearing is added and placed on the top of the valve as shown below:—



When a large valve is in a pipe which has great pressure upon it, it is advisable and often necessary to have the valve in one or two portions, one portion opening before the other, so that 'ramming' may be avoided and so that the valve may be more easily worked under great pressure.

Reflux valves.—Reflux valves are used in situations such as on large pumping mains which rise from the pumping station towards the town, so that the water in case of an accident may not run back from the town towards the pumps.

Safety or relief valves.—Safety or relief valves are placed on pumping and other mains to prevent any chance of bursting in the case of 'ramming' due to excessive pumping, undue speed in closing valves or otherwise; a relief valve must be loaded to a pressure above the ordinary working pressures likely to come against it. Spring valves as illustrated are preferable to dead-weight valves, but probably a combination of the two classes is the best form.

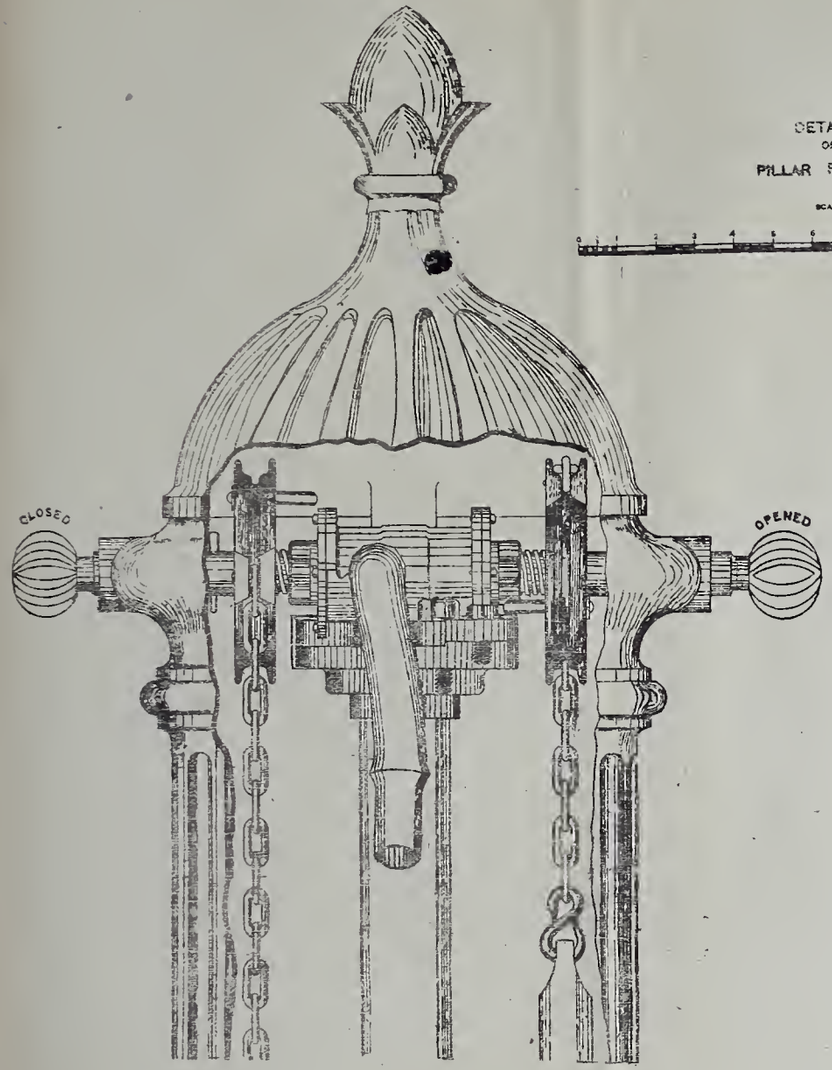
Air valves.—Air valves are required at any point where air is likely to accumulate owing to a rise in the pipe whether that rise is above the hydraulic grade or not. The ball in

ELEVATION

DETAILS
OF
PILLAR FOUNTAIN

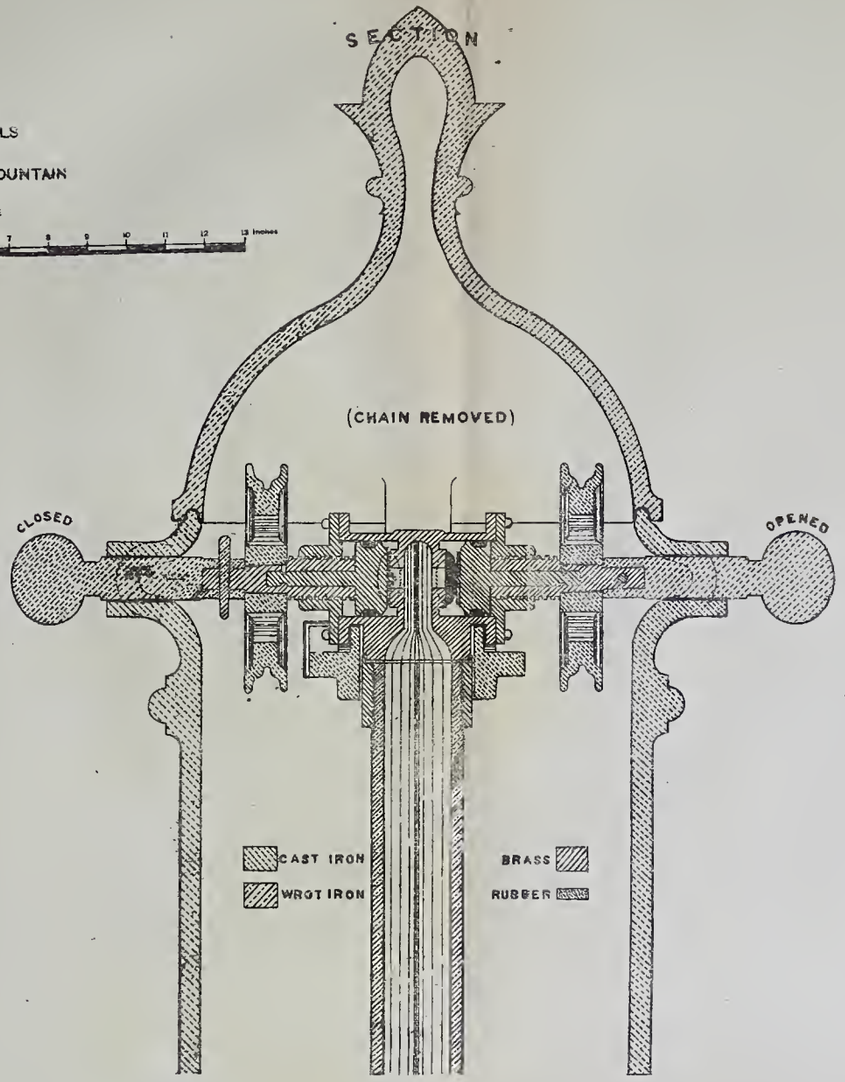
SCALE

0 1 2 3 4 5 6 7 8 9 10 11 12 13 Inches

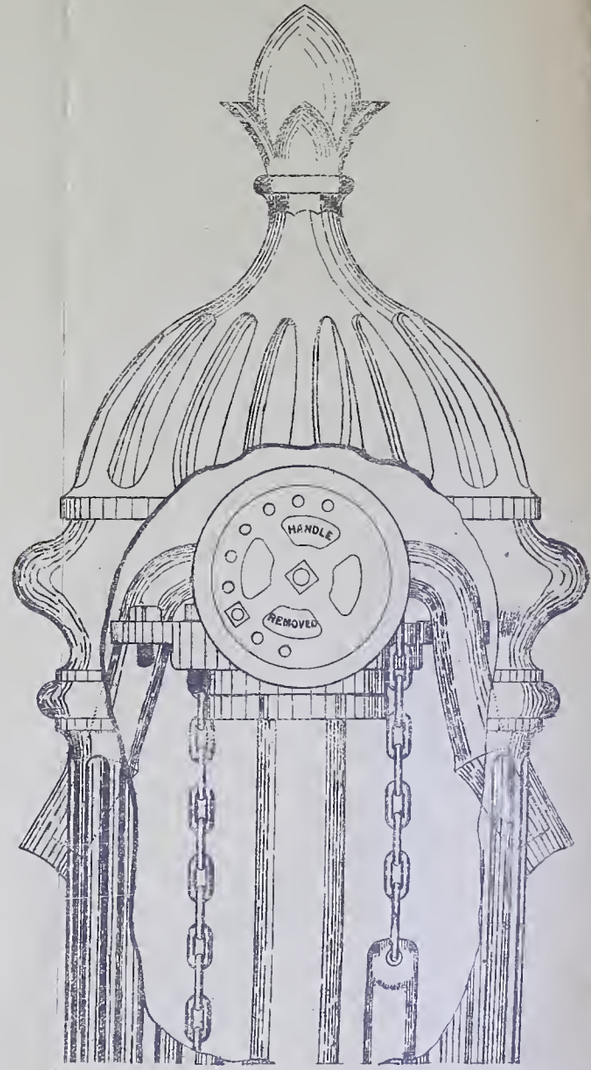


SECTION

(CHAIN REMOVED)

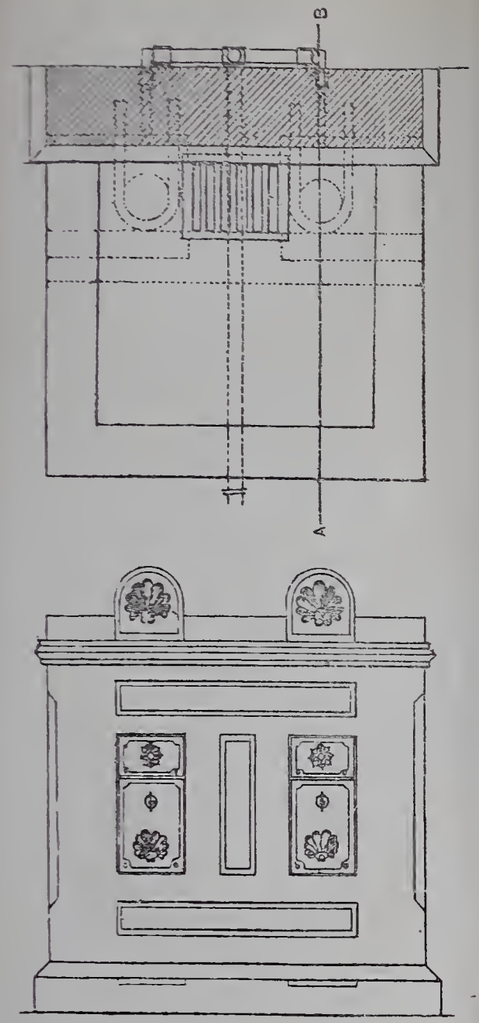


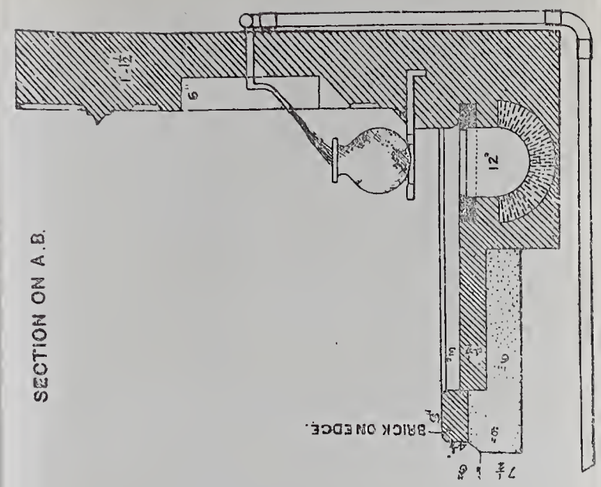
ELEVATION



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1896





DOUBLE TAP

SCALE

Inches 12 6 0 1 2 3 4 5 Feet

NOTE The details of fountains of this class are illustrated in a succeeding plate

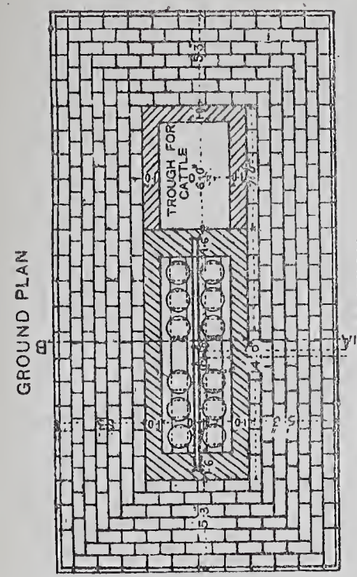
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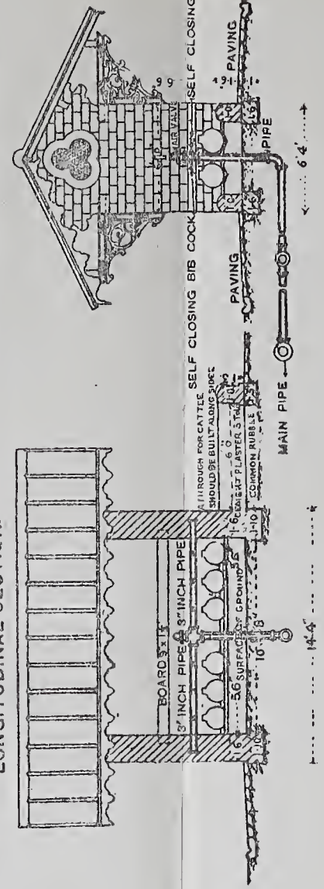
FOUNTAINS

STREET SERVICE

SCALE

0 1 2 4 6 8 Feet





BULLOCK SERVICE

SCALE

0 1 2 4 6 8 Feet

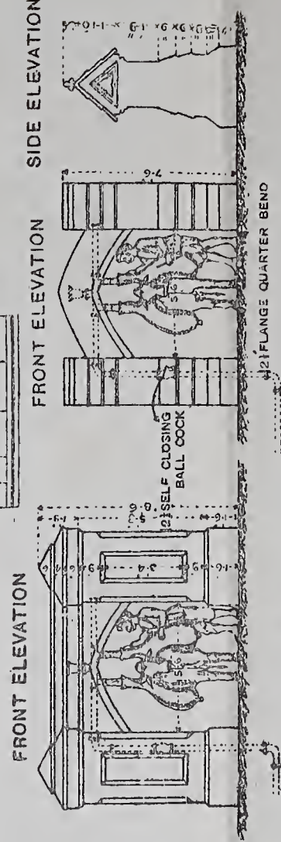


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1896

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1896

SECTION

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the valve is made of some material lighter than water (compressed guttapercha is a usual material); the ball thus floats, as long as there is no air in the pipe bearing against the cover above it and closing a small hole through the valve cover. If air accumulates, it rises to the casing holding the ball, which then being without support falls, and the air is discharged through the hole until the water rises again. The size of the balls are varied with reference to the maximum pressure on the mains.

Stand pipes or fountains.—Stand pipes, very often called 'fountains,' may be of varied design. Those in use by the author's department are shown on plates accompanying, where there is also shown a design for the Karachee fountain, which is a suitable plan, where a large number of people have to be supplied or where puccally bullocks draw water. The size of the fountain discharge cocks and their number must be proportioned to the number of persons using a particular fountain; the number of discharge cocks must be such that no person has to wait more than a minute or so to obtain an ordinary chatty full of water.

Self-closing taps necessary.—One important matter to be attended to in the construction of fountains is that the taps shall be self-closing and adapted to the maximum pressure under which they will be worked; this is a necessity in India where people are careless of water and great waste ensues. The details of the pillar and wall taps adopted for use in the Madras Presidency are shown. These designs are such that the fountains and their parts can be easily taken to pieces and repaired, and if properly weighed and kept in order are perfectly water-tight.

Cistern fountains are sometimes found convenient; these are in their simple form, cisterns placed at or above ground level, the cisterns being filled at times of least demand and controlled by a ball valve. The taps are placed in the walls of the cisterns. These cisterns are suitable for places where the pressure is low during the hours of maximum demand, as they can be filled during the night. They should be designed to contain a 12 hours' supply for the population using them.

Hydrants.—There are many forms of hydrants, but those more commonly used are the 'Ball' and 'Screwdown' hydrants; both of these classes are illustrated on the plate facing page 366. Hydrants are used (1) for fire purposes; if the pressure is considerable, the hose pipe may be attached directly to the hydrant and the water discharged

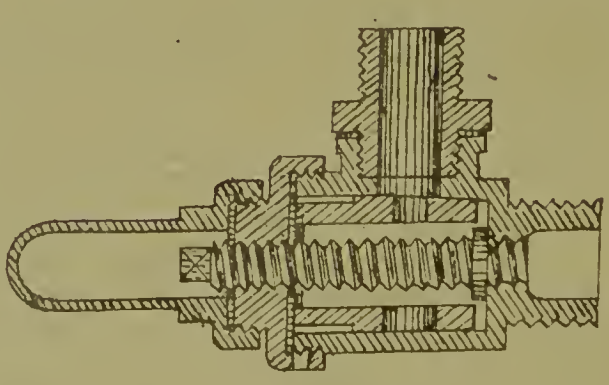
on to the fire through a nozzle of proper size; if the pressure is low, the hose pipe will lead the water to the supply tank of the fire engine where the necessary pressure will be applied; (2) for filling water carts, flushing drains, &c. Hydrants should be put down as closely together as possible for both purposes; security is ensured in the one case and economy in the other (*vide* street watering); the more valuable the property, the more dense the population, the more hydrants are necessary; they are always a costly item in a water-supply scheme. The best position for hydrants is near street crossings so as to command all streets converging to such point. Hydrants, of course, cannot be placed on small mains, that is to say on those less than 3 inches in diameter, and even on each such mains one, or at most two, hydrants could be in use at one time, the ordinary diameter of the outlet of a hydrant being $2\frac{1}{2}$ inches.

Ball hydrants.—A ball hydrant may be erected permanently above the street, or the portion above the street level may be attached as required; the hydrant is opened by the ball (held up by the pressure of water) being pressed down.

Screw-down hydrants.—Screw-down hydrants are usually below street level and are cheaper and more easily fixed and used than ball hydrants which require special apparatus to open them. In using these screw-down hydrants, copper stand pipes may also be attached, and to this the hose may be attached instead of to the hydrant itself when the hose is apt to 'kink' and limit the discharge.

Stop cocks.—Stop cocks are small valves used on service pipes and are made in many various designs.

Ferrules.—Ferrules are used for connecting service pipes to the main, whether these are of lead or iron. Service pipes ought never to be screwed to the main direct. A very good design of a ferrule is that designed by Mr. Hughes, C.I.E.; it is illustrated below:—



Its advantages are described thus.—It meets a want hitherto felt in those water works supplying water in proportion to the rent paid by the consumer.

The adjustment of the cock is effected by varying the position of the inner barrel: this can be done without emptying the communication pipe or interfering with the pressure on the main. It cannot be tampered with, and may be set to flow of water varying from the smallest quantity prescribed by the regulations up to full bore.

The figures marked on the upper edge of the internal movable barrel correspond to the various flows prescribed by the regulations.

If provided with an iron cover or ready means of access, *no stop cock is required on the communication pipe.*

The adjustment of the flow is quite independent of the action of closing and opening the cock, so that the consumer, though unable to tamper with the inner barrel and thus interfere with the prescribed flow of water, can close the cock for repairs in the house service, and reopen it without sending for the water works officials.

Surface boxes.—Surface boxes or valve and stop cock covers are of varied design and generally made of cast iron. In India it is very necessary that they should have hinged covers which can be locked, otherwise curiosity causes injury to the covers (which sometimes also disappear entirely) and often to the valves themselves.

In selecting appliances for Indian water-supplies, it is desirable to adopt such as are simple in construction especially for an up-country town not within easy reach of some good workshop; it is always advisable to keep in stock a quantity of spare fittings such as fountain handles, India rubber rings and discs, India rubber sheeting, yarn, wrought-iron piping, bends, knees, couplings, &c., so that repairs may be readily executed and waste of water avoided.

LAYING AND JOINTING OF PIPES.

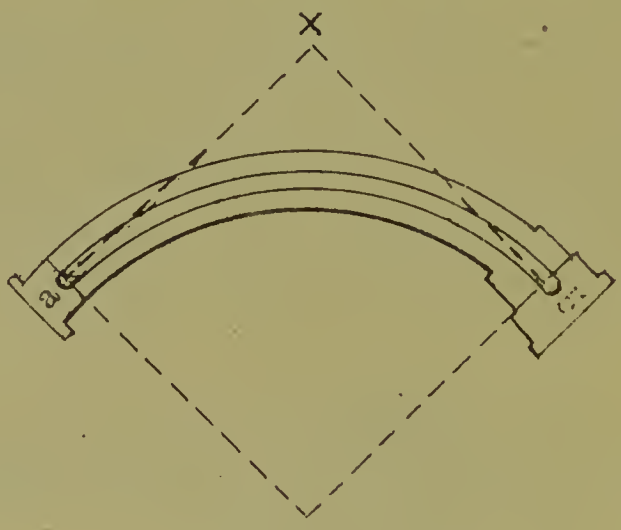
This is a very important work in any water-supply scheme; the manner in which it is executed has a very material effect on the cost of after-maintenance.

Survey necessary.—The best preparation for pipe laying is found in a careful survey and levels of the proposed line. Cross streets, bridges, culverts, existing pipes and drains should all be indicated on the plans and sections. It may not be

possible in making the first survey to locate the exact line of the pipes, but this must be done before the work is begun and the details on the section can then be accurately filled in. In spite of all care in this direction, it will be possible only to minimise difficulties and unforeseen obstacles which are constantly coming in view as pipe-laying proceeds.

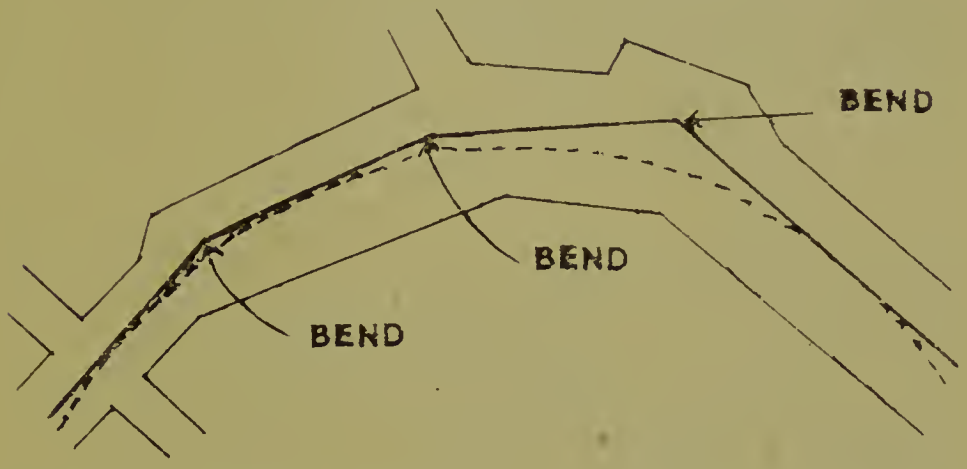
Laying out pipe lines, &c.—After the lines have been finally located, the exact centre line of the pipes and the situation of each bend, branch, valve, hydrant, &c., should be marked on both plan and section and the site of each should be carefully determined and marked on the ground; at places such as street crossings or other places where numerous valves, branches, &c., are to be placed, it may be necessary to make an enlarged drawing. The 'bends' will probably have been ordered before the exact centre lines of the pipes have been determined (and indeed that line may have to be altered more than once after laying it out) so that it is always well to have a surplus number of bends on hand.

Locating pipe lines.—In laying out the centre lines of the pipes, they should be laid out, as far as possible, at the angles shown on the plan and for which the bends have been ordered. The position of the bends may be fixed by having a wooden model made of each class and laying it down at the angle of intersection of the straight lines on either side of it and marking the ends with iron spikes thus at a and b, ax = bx.



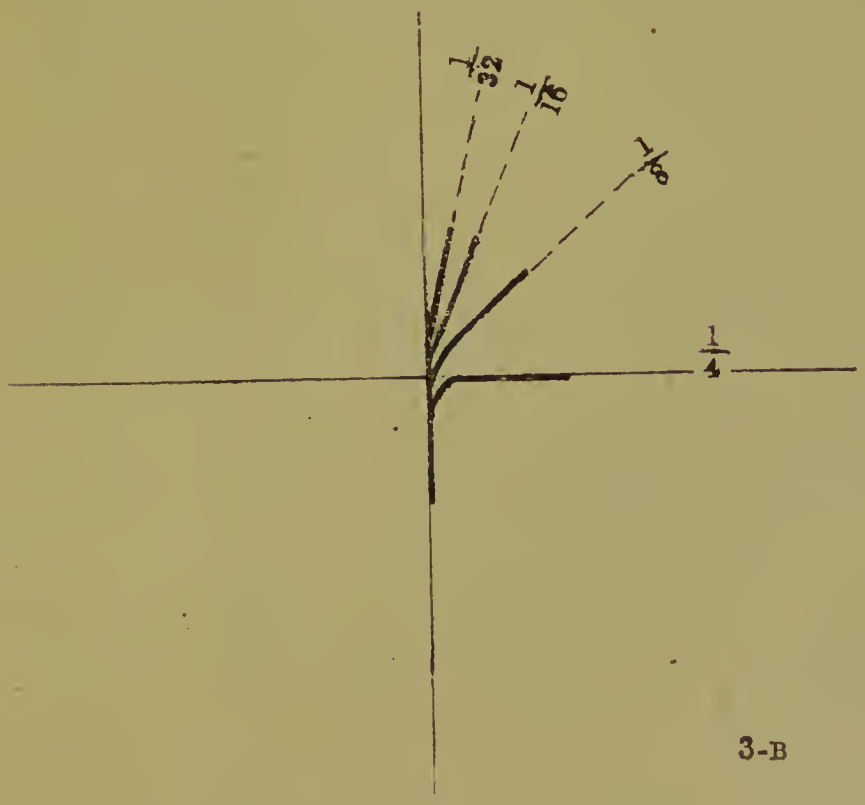
Pipes should be laid in straight lines.—It is not desirable to lay pipes along curves, thus, for instance, in a street such as shown below, it might be possible to put in a curve (dotted line) throughout. This, however, would entail

that no spigot was properly placed in its corresponding faucet

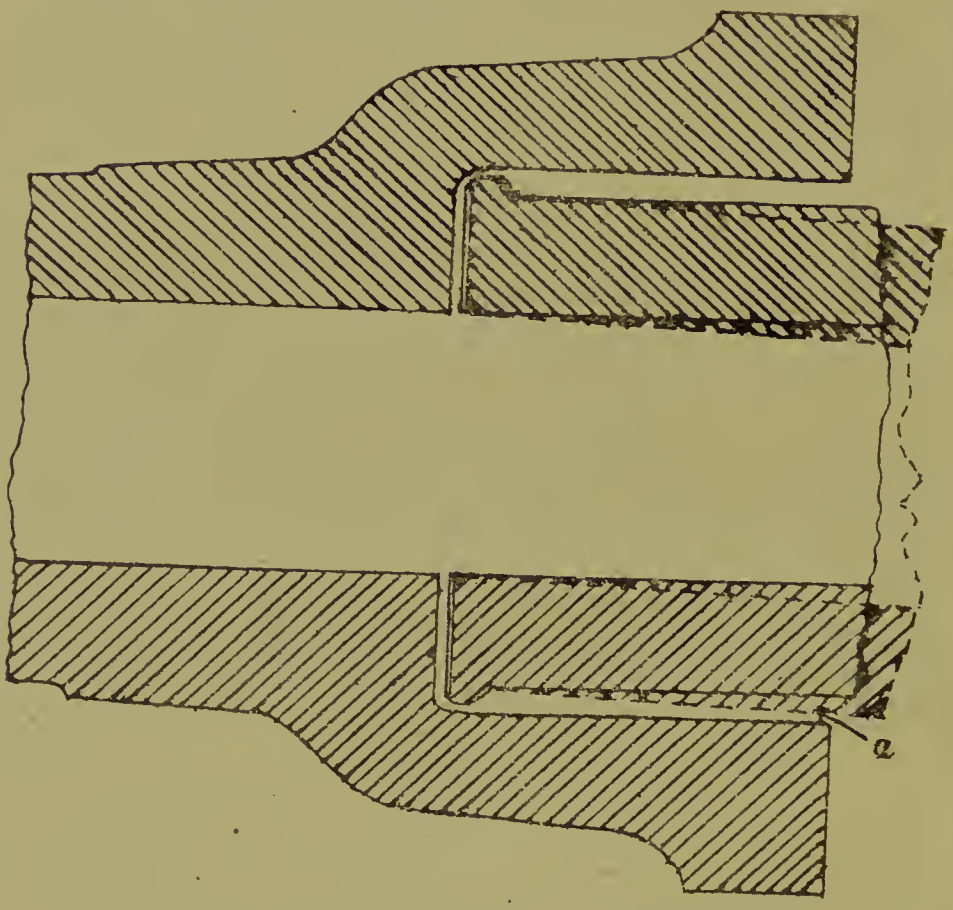


and it is much more satisfactory to lay the pipes as shown by the full lines with three bends. Now, pipe layers will and do lay pipes not only along curves of large radius, but along very sharp curves and through very crooked streets without bends at all; it is sometimes necessary to lay pipes at an angle when 'bends' are not available or suitable but it is not a desirable plan unless the angle is very slight; pipe layers require careful watching to prevent them so laying pipe lines.

Bends.—Bends are ordinarily designated as $\frac{1}{32}$d, $\frac{1}{16}$th, $\frac{1}{8}$th or $\frac{1}{4}$; these figures represent 'bends' made so that the angles from the straight lines on one side of the bend are respectively $11\frac{1}{4}°$, $22\frac{1}{2}°$, 45° and 90°.



Laying pipes along curves.—While it is not advisable it is possible to lay ordinary or plain straight spigot and faucet pipe at an angle with each other. This requires that each pipe shall be laid to a greater or less extent as shown by the dotted lines :—



The maximum angle, which can be obtained at each joint, is determined by the least thickness of lead required at the point (*a*) and the wider or thicker the joint is proposed to be the greater will be the possible angle. Large pipes having thicker joints can be laid at greater angles than pipes of small diameter, but, as it is desirable that the larger pipes should have thicker joints than smaller pipes, so also it is desirable that the joint between pipes laid at an angle to each other should be thicker in proportion to their size. Everything depends on what is the least thickness of lead which can be depended on to make a safe joint and whether the lead be

properly run in and the yarn caulked into the joint. Ordinarily it will take seven straight pipes laid in this way to pass round a curve giving an angle equal to an $\frac{1}{8}$ bend. If it is necessary to lay pipes along curves these should be laid out carefully by means similar to the methods employed on railways, and curve tables should be framed for these curves, which will be of much less radius than those found in ordinary curve tables.

Reception and delivery of pipes.—The pipe lines having been satisfactorily located and the position of the various appliances having been determined, the next matter for attention is the delivery of pipes on the ground. These will be received from a ship or from canal boats or by rail and it is the best plan in making a contract to specify that pipes will be taken over only at the town where the pipes are to be used; this saves infinite trouble in regard to breakages, accounts, &c., and though the pipe contractor will charge for the work, there is no doubt that a double agency would generally be more expensive.

Examination and distribution of pipes.—The pipes having been unloaded should then be examined; they, under the specification already referred to, will have been marked with their numbers, weight and diameters and the quantities can be thus easily checked; sound pipes may then be transported to either selected depôts in the town (the pipes to be deposited in each depôt having been previously decided upon) or directly to the roadway on which they are to be used. Considerable judgment is required to deposit pipes and distribute them, so that the exact number and class for each length of street are available and so that traffic, passengers or house owners are not inconvenienced by their deposit; it is therefore desirable in India that the streets should be surveyed in view to the deposit of pipes and careful instructions given to intelligent agents who should accompany the cart men to their destination. This may seem a refinement, but it is true economy in the end especially when heavy pipes are being used. Small pipes of less than 3″ diameter are best deposited with the valves, hydrants and other fittings in depôts convenient to the work. The pipes, when laid down on the streets, should be laid with their faucet ends all pointing in one direction, that is, in a position similar to that in which they are to be laid, and it is usual to place the spigot end of a pipe next the supply end; this cannot always be arranged and in streets mains fed from two directions, one half the

pipes will lie one way, the other half the other. Again the pipes ought to be laid on the side of the street or side of the proposed pipe trench opposite to that on which the excavated earth will be placed; this avoids the cost of lifting the pipes over embankments of loose earth. This is a great saving when working with large heavy pipes, as they can be rolled easily to the trench if the above conditions are observed.

Inspection of pipes.—Before any pipe laying is begun all the pipes must be carefully inspected. It is likely that a proportion will be found cracked; in ordering pipes, therefore, a percentage of each class in excess of requirements must be ordered to allow for cracked pipes, breakages, &c.; whether cracked pipes are to be accepted at all is a matter of specification and agreement. Cracks in pipes can be readily detected by striking the pipe with hammer; cracks will usually be found at the spigot end of a pipe and it is sometimes specified that each pipe shall have an iron ring shrunk on to it before being despatched; this is desirable in all cases of pipes which will require much handling or to be transported long distances by road or for use in places where it will be difficult and costly to obtain odd pipes.

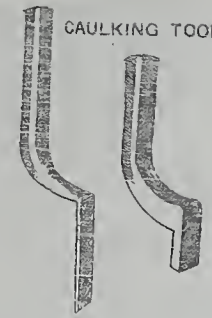
Cutting pipes.—In cutting off the piece of pipe which is cracked, the cut must be made about 6 inches above the visible end of the crack because the jar caused by cutting may cause the crack to run further up the pipe. Cut pipe joints, especially if originally of the turned and bored class, entail more expensive joints than originally intended, and therefore it is only fair to debit the pipe supply contractor with an amount in excess of the actual value of the length of pipe cut off sufficient to cover the extra cost of the joint.

Depth at which pipes should be laid.—A further matter to be decided before pipes are laid is the depth at which they are to be so. Here in India the effect of frost is not to be considered but that of heat. It may, however, be said that, when once the water is in the pipe, its temperature varies very little if the pipe is covered by earth to any extent. It is therefore a matter of convenience and probably the best manner to determine the depth at which pipes should be laid is that on which the following table is based, viz., that they shall be laid at a depth below ground such that the spindles of valves on such pipes shall not be nearer the road surface than 4 to 6 inches. The amount of excavation per lineal foot is also shown in the table, slopes of $\frac{1}{4}$ to 1 being allowed :—

TOOLS FOR LAYING AND JOINTING PIPES

YARNING IRON

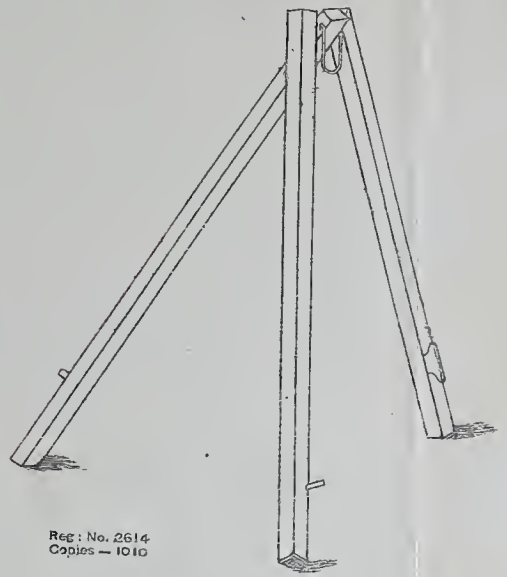
CAULKING TOOL



CUTTING OFF TOOL

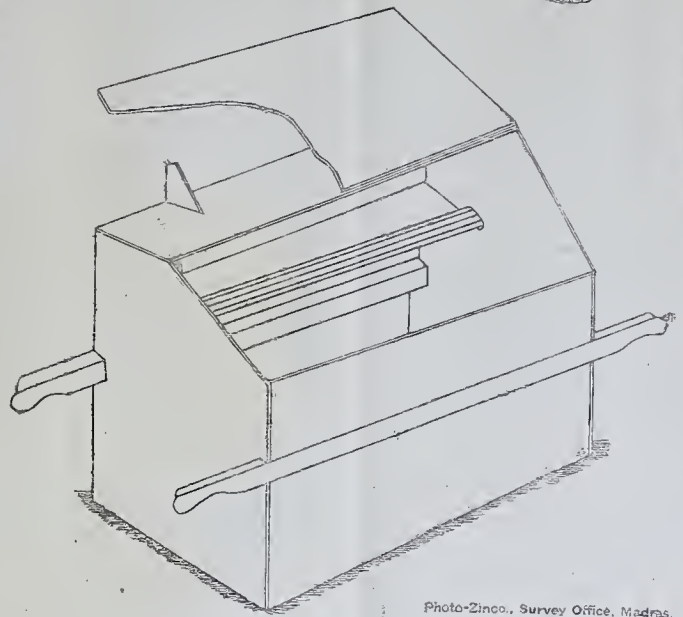


DERRICK



Reg: No. 2614
Copies — 1010

TOOL BOX



CAULKING HAMMER



CARRYING STICK



TAMPS

IRON



WOOD



FURNACE OR LEAD KETTLE

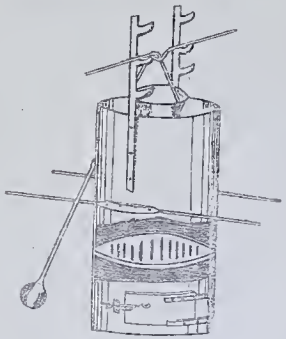


Photo-Zinco., Survey Office, Madras.
1896

Dimensions and cubic contents of trenches for laying pipes.

Bore of pipe.	Height of valve from bottom of flange to top of spindle.		Depth of bottom pipe below ground.		Width at bottom.		Sectional contents per foot length.
INCHES.	FT.	IN.	FT.	IN.	FT.	IN.	C. FEET.
2	1	9	3	0	2	6	9·75
2½	1	10½	3	0	2	6	9·75
3	1	11½	3	0	2	6	9·75
4	2	2½	3	0	2	6	9·75
5	2	6¼	3	0	2	6	9·75
6	2	7½	3	0	2	6	9·75
7	2	11	3	0	3	0	11·25
8	3	2½	3	4	3	0	12·72
9	3	6	3	7½	3	0	14·12
10	3	9½	3	11	3	0	15·60
12	4	3	4	4½	3	0	17·87
14	4	9	4	10¼	3	0	20·59
15	5	0	5	1½	3	0	21·91
16	5	3	5	4½	3	0	23·34
18	5	6	5	7½	3	0	24·78
20	5	10	5	11½	3	0	26·75
21	6	1	6	2½	3	0	28·26
22	6	4	6	5½	3		29·79
24	6	8	6	9½	3		31·96

Excavation of pipe trenches.—The levels of the bottom of pipe trenches should be carefully determined and the officer in charge of the work should give level pegs at frequent points so that the trenches may be fairly graded. The earth from the trenches ought to be thrown all on one side if possible, street crossings ought not to be cut through until actually necessary, and the trenches ought to be protected and at nights lighted. Before pipe laying is begun about 100 yards of trench should be fully executed and the excavating and pipe-laying gangs should be so proportioned that their work proceeds at the same rate per yard per diem.

Pipe-laying tools.—On the plate accompanying are figured some of the tools used in pipe laying. The derrick may be formed of tough jungle wood or of teak poles 4″ × 4″ and 14½ feet long held together by a 1-inch bolt at the top; the link should be of ⅞ inch iron. The lower ends of the poles may be shod with iron and a spike fixed to prevent slipping; a large cleat for catching the ropes should be fixed into one leg of the derrick and long hard wood pegs to act as handles in moving the derrick fixed on the other two legs

as shown for a 6-inch pipe; 8-inch double blocks will give power enough for a 15-inch or 18-inch pipes, a triple and quadruple block may be necessary. For pipes under 6-inch diameter a smaller derrick may be used.

The carrying sticks illustrated are useful for lifting and placing the smaller pipes, but pipes of larger diameter must be rolled to the site where they are required. Chisels for cutting pipes are those ordinarily used for cutting cold iron. Four yarning and four caulking tools form a set, varying in thickness from $\frac{1}{8}$ inch to $\frac{3}{8}$ inch.

Laying pipes.—Light pipes 4″ to 6″ when about to be laid are carried to the trench, as before stated, by the carrying sticks inserted at each end of the pipe; other pipes are rolled to the trench. The pipes are then supported on skids or small beams placed over the trench slung by the derrick, the skids removed and the pipe lowered down. At the same time the foreman in the trench is inserting the spigot end into the last pipe; the pipe is then aligned; the next pipe is then brought down and is used to ram the preceding pipe home. When the pipe is thoroughly 'home,' the pipe is jointed with cement or lead as required.

Jointing pipes.—Cement joints may be of any reasonable proportion of sand and cement; the main point is to see that it such as does not crack because the actual joint is formed by the turned and bored faces which should be carefully washed with a mixture of cement and water before being inserted one into the other. Lead joints are made of by a combination of yarn and lead. The 'yarn' may be jute, hemp, old rope, &c., but '12-thread Russia gasket' tarred is recommended; larger sizes may be used for pipes above 18 inches in diameter. The yarn must be cut into pieces long enough to go round the pipe and lap a little. The depth of yarn and lead is usually specified; as yarn is cheaper than lead, care is necessary to see that the proper depth of lead is always put in. With lead jointed pipes, the pipes must, before the yarn or lead is inserted, be made concentric with each other by means of feathers or wedges so that the joint is of the same thickness all round. To guide the molten lead into a joint there must be a roll of clay (ground fire clay is best) or a rope yarn core. 'Joints' made of canvas, India rubber and steel which are fastened tightly round the pipes are used instead of the clay. A clay roll is placed round a pipe close to the faucet face of the other, the two ends of the rope are brought together on the top and a convenient hole left there

for pouring in the lead; the lead should be poured in slowly and should be hot enough to run freely. When cold, the clay roll is removed and the joint set up as described in the specification following:—

Specification for conveying, laying, and jointing cast iron pipes, bends and branches, and for fixing and setting up sluice valves, air valves, hydrants and fountains, &c., for the Municipal Council of ..... as set forth in detail in the accompanying schedule.

RECEIPT, TRANSPORT AND CUSTODY OF MATERIAL.

1. The pipes and other materials as set forth in the schedule will be supplied to the contractor by the Council of. . . .

2. The contractor is required to provide all labour, plant, tools, lead, rope, yarn, cement, &c., necessary for the carrying out of the work as hereinafter detailed.

3. The contractor who supplies the pipes will unload them and the Engineer will provide an agency to supervise the receipt of pipes and materials by the laying contractor, and the said contractor will be required to grant a receipt for all articles received by him. All articles taken over by him will be considered as having been received by him in good condition unless otherwise noted in writing by the officer in charge on the contractor's receipt. It shall be the duty of the contractor to reject any articles which are found to be in any way cracked, broken or deficient of any portion. When any articles are found cracked, broken or deficient at the time of delivery, the fact shall be immediately notified to the agent, and the agent shall at once notify the same to the material contractor or his agent for receipt. Any article which may be slightly chipped or broken and which the Engineer's agent considers may be used on the work shall be received by the contractor, the item being marked by the said agent as broken or deficient as the case may be in the contractor's receipt note. The articles shall be removed by the laying contractor from the railway yard immediately they are unloaded, and he shall be responsible for any demurrage which may be charged from his delay in removing material to allow room for further unloading, and he shall stack them in such quantities and at such places as the officer in charge considers most suitable.

4. The distance from the point of receipt by the contractor and the farthest point of delivery by him is.....

miles ..... The centre of the bulk of the work is about..... ..... from the point of receipt.

5. The contractor shall provide a covered store in a position to be approved of by the officer in charge where articles, such as valves, fountains and smaller articles, may be safely deposited until wanted for use.

6. All pipes, branches, &c., shall be deposited by the contractor in proximity to their position on the work where they are to be used, at such time as the officer in charge considers proper. This will usually be just before they are to be laid in the trenches, as it is not intended they should be left to lie about the roads longer than is absolutely necessary.

7. The contractor, however, will not be permitted to deposit materials on any side which shall inconvenience the public, and the sites of deposit shall be approved of from time to time by the officer in charge of the work. The officer in charge may require the contractor to remove any materials which are a danger or inconvenience to the public, and the former shall be sole judge of such inconvenience or danger.

8. The contractor shall be responsible for the safe custody of all materials handed over to him by the agent, whether such materials be deposited in the store referred to in paragraph 5 or deposited on sites adjacent to their position in the work, subject, however, to the directions and control of the officer in charge for the purpose of inspecting, weighing or testing the pipes and materials as he shall see fit to do.

9. Any pipes, valves, fountains or materials which shall have been handed over to the contractor in good condition and which thereafter shall be damaged before, when, or after, being placed in the work, shall be paid for by the contractor at the rate paid for such articles by the council *plus* 10 per cent. in excess of such rate. Should he crack or break the spigot ends of any pipes after receiving them, he shall (if the cracked or cut portion be less than half the length of the pipe) cut the damaged part off at his own expense, and pay for the actual length cut off *plus* 10 per cent. extra in excess of such rate. Should the damage be at a socket end or reach to half the length from the spigot end, then he shall pay the cost of the whole pipe *plus* 10 per cent., and the pipe then becomes his property to dispose of as he may think proper.

Excavation of Trenches.

10. The estimated depths of trench for the various sizes of pipes are shown in the schedule, but the officer in charge

shall have power to alter their depth and breadth as he may consider advisable. The quantity of each description of soil or rock entered in the estimate is not guaranteed as correct, and the contractor will be paid at the tender rate only according to the actual quantity of each description found after excavation. The contractor shall have no claim if the actual quantities of rock or soil excavated vary from the schedule or if the depth be less than in the schedule. The officer in charge will also regulate the order in which trenches for mains or branches are excavated.

11. In digging the trenches, which shall ordinarily be along one side of the streets in which pipes are to be laid, the contractor shall first remove the metalling, where such exists, and shall carefully deposit it so that it shall not be mixed up with earth, mould, &c., from the trench, and ordinarily he shall lay the metal so removed on one side of the trench and the earth on the other side.

12. The amount of excavation in the schedule is calculated on the basis of the slopes standing $\frac{1}{4}$ to 1 for the period necessary to allow of the pipes being laid and tested, and the contractor shall not be entitled to make any claim for any place where the earth will not stand at such inclination, as he is expected to allow in his schedule rates for any shoring, planking, baling, &c., which may be necessary.

13. In forming the trenches in earth they shall be cut so that the bottoms have regular beds, and no filling in with loose soil will be permitted. Should the excavation be taken out deeper than ordered, the pipes may be laid at that depth (the contractor being paid only for the depth ordered) or the level be brought up with earth or gravel, watered and rammed as may be ordered. The pipes in all instances shall be laid on a firm foundation.

14. Where the excavation is in rock, a trench only sufficiently large to admit of the pipe being laid shall be cut, and where the inequalities in the rock-bed cannot be levelled except at great expense, the hollows shall be filled up with sand, and such sand-filling shall be brought up one inch above the top of the pipe, when ordinary soil shall be filled in or ordinary small rock spoil may be used, provided it is mixed with sufficient *moorum* to thoroughly fill the interstices. Should the rock require blasting, the blast hole shall be covered with a strong wooden crib approved of by the officer in charge. The contractor shall also observe all such other regulations for the safety of the public as that officer may issue in

writing, failing which that officer will carry out the work departmentally, the cost of which (*plus* 10 per cent. for supervision) will be deducted from the contractor's bills.

15. At road crossings not more than one-half the breadth of a road shall be opened at one time, nor shall two or more roads at their junction be opened except in such manner as shall avoid all interference with traffic. The contractor shall provide suitable planking over trenches for foot, cattle, or vehicle traffic where the officer in charge thinks necessary.

16. Open or newly-filled trenches shall be protected with a strong bamboo or other fencing during the day, and in addition thereto at night the contractor shall provide red lanterns and watchmen. The responsibility for any accident which may occur through insufficient fencing or lighting shall be that of the contractor. The contractor shall be responsible for any damage done to any adjacent property by his operations. Should the fencing, lighting, or watching be at any time insufficient, the contractor shall be written to to make the same satisfactory to the officer in charge; failing to do so within twelve hours afterwards, the officer in charge will do so, deducting the cost of the same, including supervision, from contractor's bills.

17. The pipes shall ordinarily be laid at the depths noted in the schedule, but before commencing to lay any pipes the contractor shall ascertain from the officer in charge of the works whether owing to the presence of drains, cess-pools, or other causes, the schedule depths require to be increased or decreased, and on obtaining orders in writing the contractor shall lay the pipes at the new depth. Payment will be made for only the amount of excavation ordered to be executed, and not for any extra. Payment for works, for which quantities do not appear in the schedule, will be paid for at the schedule rates according to the actual quantity of work of each description for which the contractor may have received orders in writing.

Laying and Jointing Pipes.

18. In laying turned and bored pipes the following instructions shall be observed. The pipes, before being laid, shall be thoroughly cleaned, and the turned and bored surfaces made bright by scrubbing. The turned and bored surfaces shall be slightly coated with cement-wash; when the spigot end of a pipe has been inserted in the faucet of another, the former pipe shall be driven home with a heavy

wooden rammer. Where the pipes are above 12″ in diameter, the succeeding pipe held in a sling ready for lowering may be used instead of a rammer, a wooden 'bumper' block being held against the faucet end of the pipe being laid. After a pipe has been rammed home, the joint shall be filled with neat Portland cement, which shall be thoroughly well packed.*

19. For plain spigot and faucet joints, cut pipes, and other lead joints the following instructions shall be observed. After the pipes or specials are placed into each other and laid in the exact position they are to occupy, the joints will be formed as follows. At least one complete lap of clean hempen yarn shall be forced into the bottom of the socket. Several laps of tarred yarn shall then be forced into the joint so as to leave at least the depths of joint for the lead as noted below :—

Pipes	2″ to 5″	diameter	.. ..	$1\frac{1}{2}$″
,,	6″ to 12″	do.	.. ..	2″
,,	14″ to 18″	do.	.. ..	$2\frac{1}{4}$″
,,	20″ to 24″	do.	.. ..	$2\frac{1}{2}$″

The lead shall then be put in, and the joint filled at one running with lead flush with the outside of the joint, which shall be 'set up,' when cool, until the lead is at least $\frac{1}{8}$th inch within the socket. The quantities for each class of pipe are shown in the schedule.

20. *Bends.*—The net length, measured on the curve, will be paid for at the same rate as for plain pipes.

21. *Branches.*—Supposing it to be, say, a 12″ × $2\frac{1}{2}$″ branch, the net length of the 12″ length (3′ $3\frac{1}{2}$″) will be paid for at the rate for 12″ plain pipes, and the branch part at the net length for a B class pipe of ($12\frac{1}{2}$″—$6\frac{9}{16}$″) say 6 inches.

22. *Tapers.*—The net length will be paid for at the rate for plain pipes of the largest diameter of the taper. For example, a taper of 4 feet in length 24″ × 22″ will be paid for as 4 feet of 24″ plain pipe.

23. *Collars.*—For laying collars, the gross length of the collar will be paid for at the same rate as the pipes they are used to cover. For example, a 12″ collar, though of greater

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* The filling of a joint ought not to be done until about 100 feet of piping in advance thereof has been rammed home.

diameter than a 12″ pipe, will be paid for as a foot of ordinary 12″ piping. For jointing, the joint at either end of the collar will be paid for at the rate specfied in the tender.

24. *Cutting pipes.*—The work of cutting off the ends from pipes damaged before delivery to contractor, or from sound pipes which it may be necessary to cut at curves or in order to lay tees, valves, &c. in particular positions, shall be paid for at the tender rate according to the actual number of pipes of each size which it may be necessary to cut; the pipes damaged in transit before delivery to the laying contractor should not therefore, have their damaged portions cut off till they are actually required for use near bends, valves, &c. It is, of course, impossible to state the number of each description of pipe which may require to be cut; tenderers will bear this in mind when entering rates for cutting, viz., that the rates are to be irrespective of the number to be cut, whether small or large.

25. *Testing pipes.*—The pipes after being laid and jointed shall be tested in such lengths and at such pressure as seems to the engineer desirable. Such pressure, however, shall not exceed 50 per cent. in excess of working pressure. The testing will be done departmentally, and any joints leaking or sweating shall be made good by the contractor at his own cost. Should any joints leak or sweat at the second testing, the cost of further tests will be deducted from the contractor. Before testing, the trenches (except for 18″ on either side of each joint) shall be filled up to a depth equal to not more than one-half the diameter of the pipe in the trench. To prevent unnecessary trouble and cost in testing, all connections, such as fountains, hydrants, air valves, &c., shall be made and completed before testing is commenced; a main or branch must not be tested and then fountains, &c., built at some future time.

26. *Filling trenches.*—After the testing has been completed, the trenches shall be refilled in the following manner. The earth must be well punned in layers not exceeding six inches in depth, and watered if the officer in charge considers it necessary, the original metalling being replaced, well rammed, and the whole surface made smooth and neat. The height of the filling (including metalling) above the original surface level shall not exceed one inch per foot of depth of trench. The contractor will be held responsible

for any subsidence in the line of the trenches, which may take place at any time within six months after the total completion of his contract, and should he fail, on any occasion to attend when any such subsidence shall occur and within twelve hours of notice in writing, to fill up the subsidence after removing the metal which he shall again replace, the necessary repairs will be done at the cost of the contractor.

27. *Surplus earth.*—The surplus earth from the trenches shall be carted away to such sites within municipal limits as shall be fixed by the council. The cost of such cartage shall be included in the contractor's tender for the excavation.

28. *Sluice valves, air valves and hydrants.*—The sluice valves, air valves and hydrants on the pipes shall be cleaned, examined and placed in the positions to be indicated by the officer in charge, and they shall, as far as practicable, be placed in positions where there is the least traffic. The valves when being fixed shall be supported so that there shall be no strain on the flanged or other joints.

29. *Valve pits.*—The valve pits shall be constructed according to drawings furnished to the contractor, the depth being increased when ordered by the officer in charge. The depth of concrete or masonry shall also be increased when ordered in writing. As the pipes in some instances may be required to be laid at less depths than will allow of the top of the valve spindle being below the level of the top of the road (but this may only be when the position of the valve is clear of the metalled road), the walls of the valve pit shall be, in such case, carried up to such height as may be ordered, and the pit shall have such covering as the officer in charge may order. Drawing for pits for stop cocks will also be furnished to the contractor.

30. *Hydrants, &c.*—The hydrants will be each fitted with a cast iron cover, and being fixed on an iron standard will not usually require any masonry ; cast iron pipes of $2\frac{1}{2}''$ diameter will connect the hydrant to the main. A $2\frac{1}{2}''$ sluice valve shall be inserted between the main and the standard. The connection for the $1\frac{1}{2}''$ diameter air valves shall be by means of a ferrule screwed into the main.

31. *Fountains.*—The fountains will be of the following description :—

(1) Wall tap fountains.
(2) Pillar fountains.
(3) Fountains of special design.

Item No. 3 does not form part of the contract, and special tenders will be called for when designs are decided upon. Wall tap fountains shall be cleaned, examined and placed in walls built against existing buildings or in walls built separately. All fountains shall be built according to the drawings supplied. The ground surrounding fountains shall, when necessary, be metalled to a depth of six inches for six feet around the floor of the fountain. The pillar fountains shall be as shown on drawings to be furnished to the contractor. The arrangements for the pipes, stop-cocks, &c., between mains and fountains shall be as shown on the drawings.

32. *Laying wrought-iron pipes.*—The contractor will be required to lay and joint all wrought-iron pipe connections which may be found to be required in the course of the work. An approximate length has been entered in the schedule. The rate entered by the contractor shall cover the cost of all cutting, tapping, cleaning, threading, &c.

Specification for Masonry.

33. *Brick in chunam.*—The bricks to be sound well burnt bricks $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{4}''$ ground moulded. All chunam mortar shall be composed of $1\frac{1}{2}$ slaked lime and 2 of clean sharp sand and shall be fresh ground.

34. *Chunam concrete.*—This shall be composed of one part mortar and three parts sharp gravel or broken stone. The mortar shall be as above, mixed with clean gravel or broken stone passed through a 2″ ring. The stone shall be thoroughly wet *before* being mixed with the mortar.

35. *Cover slabs* under surface boxes shall be dressed so that they do not rock on their beds, that the surface box beds fairly on them and so that the joints between the stones do not admit of earth falling into the valve pit. They shall be laid dry (not bedded in mortar) on top of the brick work, so that they may be easily removed and replaced when repairs to valves are necessary.

36. *Bed stones* for valves shall have their lower surface dressed true, and the upper surface cut out to receive the bottom of the valve case evenly.

37. *Cement plaster*, which shall not be less than half an inch in thickness, shall be Portland cement of approved brand

mixed in the proportion of one cement and two of clean sharp sand.

38. *Uncoursed rubble masonry* shall be of sound stone not less than $2\frac{1}{2}''$ in thickness with headers (through stones) 3 feet apart horizontally and 2 feet vertically. The stones shall be set with their broadest side downwards and well packed with spalls to prevent rocking.

39. *Stone coping* to fountain floors shall be truly dressed on all sides and the upper edges chamfered.

40. *Brick on edge in cement.*—The bricks shall be table moulded, $9'' \times 4\frac{1}{2}'' \times 2\frac{1}{4}''$, with a $1''$ chamfer on the top edges made in the mould. The joint shall be neat flush pointed, done simultaneously with the laying of the bricks—the rate for laying to include cost of pointing.

41. *All masonry and plaster to be kept moist till thoroughly set*, and all water used shall be free from silt; *this will be rigidly insisted on.*

42. *Work not included in the tender.*—Before executing any work which is not provided for in the tender, the contractor shall obtain an agreement in writing as to the rate to be paid for such work.

43. *Time for commencement and completion of work.*—The contractor shall, within seven days of receiving an order in writing from the officer in charge, begin work at such place as the officer shall direct. The pipes are expected in..... ..... The contractor shall, if required, proceed with the work at an average rate per month (excluding Sundays and gazetted holidays) of not less than,

200 feet	per diem for	pipes 20″ to 24″	diameter,
300 feet	do.	15″ to 18″	do.
500 feet	do.	12″ to 14″	do.
700 feet	do.	7″ to 10″	do.
900 feet	do.	$2\frac{1}{2}''$ to 6″	do.

this rate to include the excavation of trenches, laying and jointing, fixing of branches and specials, testing, and refilling and ramming of trenches including road metal. The contractor will be allowed in addition thereto one day for each fountain to be fixed, in addition to the limit of time calculated as above on the length of piping to be laid. Should the contractor fail to proceed with the work within seven days from the time the pipes have been delivered to him, or

to proceed thereafter at a rate which will ensure the pipes being laid within the contract period, the officer in charge shall (after giving ten days' written notice) have power to provide extra labour at reasonable charges for the carrying out of the work, so as to ensure its completion within due date. All such extra labour and supervision shall be deducted from any sum or sums of money due or which may afterwards become due to the contractor, and in the event of the money in the hands of the council and the money which may thereafter become due to the contractor not being sufficient to complete the work in the manner herein specified, and also to meet the liabilities which may have been incurred under the contract, or in case the council or others to whom it may be responsible sustain any loss or damage from the work not being completed within due date, then the contractor shall indemnify the council or the said persons sustaining injury for such loss or damage. The contractor will not be relieved from responsibility nor the contract considered complete until the expiration of the period specified in paragraph 26 of this specification and until the engineer has certified in writing that the whole of the works have been completed to his entire satisfaction.

44. *Payment.*—The contractor's bills will usually be prepared and submitted monthly by the officer in charge for all work done, but for slow progress the officer in charge may delay preparation of bills for such time as may appear desirable. Each payment shall be subject to a deduction of 10 per cent., which shall be retained by the council until six months after the completion of the whole work, during which period the contractor shall be liable for all defects and for all repairs found necessary. Such periodical bill shall be deemed to authorize a payment on general account subject to and pending the future complete fulfilment by the said contractor of the terms and conditions of the specification and of the contract founded thereon.

45. *Disputes.*—Should any dispute arise as to measurements or the interpretation of any of these clauses, the matter may be referred to the Sanitary Engineer to Government, whose decision must be accepted as final by the contractor.

Amount of cement, yarn and lead in joints.—The following tables show the amount of yarn and lead used in the various classes of joint which have been referred to:—

Table showing quantity and weight of Cement required for Turned and Bored Joints.

Bore of pipe in inches.	Class A.		Class B.	
	Portland cement, cubic inches.	Portland cement, weight in lb.	Portland cement, cubic inches.	Portland cement, weight in lb.
2	2·95	·15	2·95	·15
2½	3·44	·17	3·44	·17
3	3·93	·20	3·93	·20
4	4·91	·25	4·91	·25
5	10·13	·51	9·92	·50
6	11·75	·59	11·54	·58
7	13·57	·69	13·36	·68
8	17·95	·91	17·71	·90
9	20·10	1·02	19·86	1·00
10	22·01	1·11	21·77	1·10
12	28·09	1·42	27·83	1·41
14	34·80	1·76	34·52	1·75
15	37·00	1·87	36·60	1·85
16	39·49	1·99	38·93	1·97
18	43·89	2·22	43·63	2·21
20	48·60	2·46	48·32	2·44
21	57·57	2·91	57·27	2·89
22	60·41	3·06	60·09	3·04
24	65·41	3·31	65·09	3·29

Table showing quantity and weight of yarn and lead required for ordinary Spigot and Faucet joints.

Bore of pipe in inches.	Class A.				Class B.				Depth of lead, inches.
	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	
2	2·37	·14	3·53	1·44	2·37	·14	3·53	1·44	1½
2½	2·75	·16	4·12	1·69	2·75	·16	4·12	1·69	1½
3	3·14	·19	4·71	1·93	3·14	·19	4·72	1·93	1½
4	3·93	·23	5·89	2·41	3·93	·23	5·89	2·41	1½
5	10·43	·62	11·04	4·53	10·22	·61	10·82	4·44	1½
6	7·83	·47	17·08	7·00	7·69	·46	16·79	6·88	2
7	9·04	·54	19·73	8·09	8·90	·53	19·44	7·97	2
8	14·73	·88	22·09	9·06	14·53	·87	21·80	8·94	2
9	16·49	·99	24·74	10·14	16·30	·98	24·45	10·62	2
10	18·06	1·08	27·09	11·11	17·86	1·07	26·79	10·98	2
12	24·75	1·48	32·10	13·16	24·50	1·47	31·80	13·04	2
14	23·95	1·44	41·76	17·12	23·88	1·43	41·42	16·98	2¼
15	29·59	1·77	44·39	18·20	29·38	1·76	44·07	18·07	2¼
16	31·59	1·89	47·38	19·42	31·14	1·87	46·71	19·15	2¼
18	35·11	2·11	52·67	21·69	34·90	2·09	52·35	21·46	2¼
20	32·40	1·94	64·80	26·57	32·21	1·93	64·42	26·41	2½
21	33·86	2·03	67·72	27·76	33·69	2·02	67·37	27·62	2½
22	47·38	2·84	71·07	29·14	47·13	2·83	70·70	28·99	2½
24	51·30	3·08	76·95	31·55	51·05	3·06	76·57	31·39	2½

Table showing quantity and weight of yarn and lead required for cut pipe in turned and bored Socket or turned Spigot in plain faucet.

Bore of pipe in inches.	Class A.				Class B.				Depth of lead, inches.
	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	
2	2·06	·12	2·95	1·21	2·06	·12	2·95	1·21	1¼
2½	2·40	·14	3·44	1·41	2·40	·14	3·44	1·41	1¼
3	2·75	·16	3·93	1·61	2·75	·16	3·93	1·61	1¼
4	3·44	·21	4·91	2·01	3·44	·21	4·91	2·01	1¼
5	7·84	·47	10·13	4·15	7·68	·46	9·92	4·07	1⅜
6	9·09	·54	11·75	4·82	8·93	·53	11·54	4·73	1⅜
7	10·51	·63	13·57	5·56	10·35	·62	13·36	5·48	1⅜
8	13·13	·79	17·95	7·36	12·97	·78	17·71	7·26	1⅛
9	14·72	·88	20·10	8·24	14·54	·87	19·86	8·14	1⅛
10	16·12	·97	22·01	9·02	15·94	·96	21·77	8·92	1⅛
12	20·06	1·20	28·09	11·52	19·87	1·19	27·83	11·41	1¾
14	21·92	1·31	34·80	14·27	21·90	1·31	34·52	14·15	1⅞
15	25·94	1·56	37·00	15·17	25·76	1·54	36·60	15·00	1⅞
16	27·69	1·66	39·49	16·19	27·29	1·64	38·93	15·96	1⅞
18	30·78	1·85	43·89	17·99	30·60	1·84	43·63	17·89	1⅞
20	34·08	2·04	48·60	19·93	33·88	2·03	48·32	19·81	1⅞
21	32·23	1·93	57·57	23·60	32·07	1·92	57·27	23·48	2⅛
22	40·93	2·45	60·41	24·77	40·72	2·44	60·09	24·64	2⅛
24	44·32	2·66	65·41	26·82	44·15	2·65	65·09	26·69	2⅛

Table showing quantity and weight of yarn and lead required for a cut pipe in plain faucet.

Bore of pipe in inches.	Class A.				Class B.				Depth of lead, inches
	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	Tarred yarn, cubic inches.	Tarred yarn, weight in lb.	Lead, cubic inches.	Lead, weight in lb.	
2	3·53	·21	3·53	1·44	3·53	·21	3·53	1·44	1½
2½	4·12	·25	4·12	1·69	4·12	·25	4·12	1·69	1½
3	4·71	·28	4·71	1·93	4·71	·28	4·71	1·93	1½
4	5·89	·35	5·89	2·41	5·89	·35	5·89	2·41	1½
5	14·73	·88	11·04	4·53	14·43	·86	10·82	4·44	1½
6	12·81	·77	17·08	7·00	12·59	·75	16·79	6·88	2
7	14·80	·89	19·73	8·09	14·58	·87	19·44	7·97	2
8	22·09	1·32	22·09	9·06	21·80	1·31	21·80	8·94	2
9	24·74	1·48	24·74	10·14	24·45	1·47	24·45	10·62	2
10	27·09	1·62	27·09	11·11	26·79	1·61	26·79	10·98	2
12	36·11	2·17	32·10	13·16	35·77	2·15	31·80	13·04	2
14	37·12	2·23	41·76	17·12	36·82	2·21	41·42	16·98	2¼
15	44·39	2·66	44·39	18·20	44·07	2·64	44·07	18·07	2¼
16	47·38	2·84	47·38	19·42	46·71	2·80	46·71	19·15	2¼
18	52·67	3·16	52·67	21·69	52·35	3·14	52·35	21·46	2¼
20	51·84	3·11	64·80	26·57	51·54	3·09	64·42	26·41	2½
21	54·18	3·25	67·72	27·76	53·90	3·23	67·37	27·62	2½
22	71·07	4·26	71·07	29·14	70·70	4·24	70·70	28·99	2½
24	76·95	4·62	76·95	31·55	76·57	4·59	76·57	31·39	2½

NOTE.—The quantities of lead and yarn in a collar joint (as illustrated) are double those above.

Testing of joints.—It is usually specified that all pipes are to be tested before leaving the maker's works and examined before being plaeed in the pipe treneh; these tests, however, cannot ensure a perfeetly water tight pipe line; the pipe line must be tested after being laid. Many unnotieed eraeks are thus deteeted, and bad workmanship in the joints brought to light; indeed if this testing is not done, there is bound to be a large and often undeteeted waste of water. The most skilful pipe inspeetor eannot always see every joint made and even if he eould, that would not be suffieient seeurity that all the pipes and joints were water tight. Testing saves mueh expense and a eonstant recurrence of burst pipes and joints.

A testing apparatus consists of a portable hydraulic pressure pump furnished with a pressure gauge, some feet of hydraulie hose and blank flanges for attaehment to the soeket of the last pipes in eaeh length to be tested. The other end of a length may be either a valve or a blank flange; in some eases blank flanges may be done away with altogether and the pipe tested between two valves and filled and the pressure put on through some intermediate hydrant or braneh pipe. Blank flanges are furnished with eocks for the eseape of air from the pipes (this must always be arranged for) and with ferrules for eonneeting the hydraulic hose. It is necessary to 'butt' the end pipe and blank flange against a strut plaeed aeross the treneh to prevent the preeeding pipe joint 'drawing.' The simplest plan is to begin testing from the higher levels so that the water may be run from one length into another, but it may be eonvenient to pump water into the pipe at various plaees along the main. Short seetions must be tested at one time and as soon after laying as possible, so that the pipe trenehes may be filled in as soon as possible. The most diffieult pipe lines to test are those of large diameter and undulating in seetion as a large quantity of air is likely to be retained. Air valves should be put on at the summit of any undulation, otherwise it will take a considerable time to obtain the pressure required.

The pressure applied should not be less than 50 per eent. greater than that whieh will be due to the greatest pressure on the main whieh is the maximum statie head possible over the pipes if no water is being drawn off. When the proper pressure has been applied, eaeh joint must be earefully examined and any 'sweated' joint eaulked up or re-cemented. If it is desirable to fill a pipe treneh quickly, a lead joint may

be substituted for any cement joint which is not perfect and the filling in can quickly succeed. All burst or cracked pipes should, of course, be removed and replaced by others; and then there must be used what is known as a collar joint which is described further on. When the joints have been so treated and pipes replaced, the test should be again applied.

When the pipe laying is done by a contractor, it will be hardly fair to charge him with the cost of even the second test, but beyond that he ought to pay for all labour and expense of testing; he will, of course, require to pay for remaking the joints and cutting out pipes discovered to be defective.

The duration of any test is contingent on the pressure employed, the size and length of the portion of the main and whether it is undulating or otherwise.

Service pipes.—It is not desirable to determine the size of service pipes by ordinary rules; there are so many bends, branches, joints, &c., and the draught on them so irregular that it is a matter of experience as to what is the most suitable size for any particular house. With very high pressures, of course, smaller pipes are required than with low pressures; but it is convenient to have, if possible, only one or two diameters of pipe for each town and then regulate the supply to the house by partially opening the ferrule hereafter referred to or by the use of some such apparatus as that designed by Mr. Hughes and referred to on a previous page. In addition to this ferrule, there should be a stop cock on the service pipe close to the limit of the property to be served by it. All taps inside the house ought to be self-closing; there is always great waste of water with house supplies, and such taps tend to some economy especially if they are designed so as to be difficult to keep open mechanically.

House service demands.—The following table shews the discharge of service pipes 100 feet long under certain conditions; a comparison, with the average demand, in a note at the end of the table, shews what very small pipes would be suitable if the demand were limited to the quantity on which the size of the mains are based, viz., half of the total demand in six hours. In houses, however, the greater part of the supply may be taken in an hour; and therefore for a house of ten persons it might be assumed that instead of the demand being $\frac{1}{5}$th of a gallon per minute or 12 gallons per

hour, it might rise to 150 gallons per hour or $2\frac{1}{2}$ gallons per minute = 0·40 cubic foot. It must also be remembered that the 'head' tabulated is the difference between the pressure on the main and the height the tap is above the main. If the service pipe is only 50 feet in length, then only half the head in the table is necessary to ensure delivery of the quantity noted in the table.

Velocity in feet per second.	½″ diameter.			1″ diameter.			1½″ diameter.		
	Discharge per minute.		Head.	Discharge per minute.		Head.	Discharge per minute.		Head.
	C.FT.	GALS.		C.FT.	GALS.		C.FT.	GALS.	
1·4	·115	·719	2·89	·458	2·862	1·29	1·03	6·437	0·82
1·6	·130	·812	3·59	·523	3·268	1·63	1·18	7·375	1·04
1·8	·147	·918	4·34	·589	3·681	2·00	1·32	8·250	1·30
2·0	·164	1·025	5·13	·654	4·087	2·85	1·47	9·187	1·57
2·4	·196	1·225	6·95	·785	4·906	3·32	1·77	11·062	2·17
2·8	·229	1·431	8·99	·916	5·725	4·35	2·06	12·875	2·84
3·0	·246	1·537	10·07	·981	6·131	4·92	2·20	13·750	3·23
4·0	·328	2·050	17·21	1·309	8·181	8·37	2·95	18·437	5·50
5·0	·410	2·562	26·22	1·636	10·225	12·75	3·68	23·000	8·38
6·0	·492	3·075	36·95	1·963	12·268	18·00	4·41	27·562	11·81

To allow for bends, &c., reduce the discharge by 25 per cent.

NOTE.—A family of 10 persons at 15 gallons per head will draw $\frac{15 \times 10}{2}$ gallons in 6 hours = $\frac{1}{5}$ gallon per minute
= 0·032 c.ft. a minute.

Do. 20 gallons do. = 0·043 do.

House service regulations.—House service pipes are generally laid at the expense of the owner or occupier of a property, and, in large towns in India, by licensed plumbers, the owners of the water works, generally the municipal council, laying the pipe across the street and as far as the boundary of the property only. For water for domestic purposes, usually no charge is made. This supply is usually limited to a certain number of gallons per head; and this number of gallons has ordinarily some relation to the amount of water tax paid, that is, so many thousands of gallons per annum are allowed for so many annas of water tax paid; above this quantity water is charged for, as is water for manufactures, trades, livery stables, &c.

In Calcutta the diameter of the ferrule allowed is made dependent on the monthly assessment paid on the property thus:—

Monthly assessment.	Diameter of ferrule.	Area.	Monthly assessment.	Diameter of ferrule.	Area.
RS.	INCH.	SQ. INCH.	RS.	INCH.	SQ. INCH.
1 to 4	$\frac{1}{8}$	·0122	101 to 200	$\frac{5}{8}$	·3068
5 to 9	$\frac{1}{4}$	·0490	201 to 300	$\frac{3}{4}$	·4417
10 to 50	$\frac{3}{8}$	·1104	301 to 400	1	·7854
51 to 100	$\frac{1}{2}$	·1963	...	...	...

NOTE.—The pressure at the pumping stations is from 70 to 80 feet.

The following are the bye-laws relating to water-supply adopted by most of those municipal towns which have water-supplies in the Madras Presidency :—

Bye-laws framed under Section 255 *of Act IV of* 1884.

WATER WORKS.

I. HOUSE SERVICE.

Applications under section 147 (1) and (3) for the supply of water shall be in writing Form A hereunto annexed, and shall be signed by the applicant and by the owner of the building if the applicant be merely the occupier thereof.

2. Every application shall be accompanied by the payment to the municipal council of such a fee not exceeding Rs. 3 for the preparation of an estimate of the cost of laying on the water as the council may fix. Upon such payment the estimate shall be prepared under the orders of the council, and shall be delivered to the applicant.

3. Upon payment to the council of the amount mentioned in the estimate, the work estimated for shall be carried out.

4. Each house to which water is laid on shall be provided with a separate service pipe and stop cock. No two houses, whether the property of one owner or not, shall be supplied through the same service pipe.

5. Every person who desires to put an end to a contract entered into by him under section 147 (3) shall give notice in writing to the municipal council that the supply of water is no longer required by him.

6. An owner or occupier of a dwelling in any street through which no main has been laid at the cost of the

municipal council may have a street main laid down for the supply of water to such dwelling upon such terms as may be agreed upon between him and the council; but such main when laid down shall belong to the municipality.

Every such street main shall be of such diameter as the council may direct, and of such length as may be arranged between the council and the applicant.

II. Water Rates.

7. All water taken in excess of the quantity arranged under section 147 (1) to be supplied for domestic purposes, and all water, supplied for other than domestic purposes under section 147 (3), shall be paid for at such rates as may from time to time be fixed by the municipal council.

III. Meters.

8. The municipal council may fix a meter to any service pipe whenever, and for such a length of time as it may consider such fixture necessary. The cost of fixing and removing such meter shall be paid by the occupier of the dwelling to which the service pipe is attached; or, in the case of a service pipe laid down for the supply of water for other than domestic purposes, by the person on whose application such pipe was laid.

IV. Public Fountains and Stand Pipes.

9. No person shall bathe or shall wash animals or clothes at any public fountains or stand pipes, or shall draw water therefrom except for domestic purposes, without the permission of the municipal council first obtained.

V. Public Tanks.

10. No tank filled free of charge by the municipal water works shall be used for any other purposes than bathing, swimming and the washing of such clothes as the person washing them may be wearing at the time.

11. Water from public tanks may be carried away in chatties, but shall not be taken or boiled from such tanks for garden, irrigation, mechanical or ornamental purposes.

VI. Penalties.

12. Whoever commits any breach of these bye-laws shall be liable on conviction to a fine not exceeding Rs. 20,

and to a fine not exceeding Rs. 10 for every day or part of a day during which the breach is continued after such conviction.

FORM A.

To

The Chairman,

Municipal Council, ...

SIR,

I, the $\frac{\text{owner}}{\text{occupier}}$ of the undernoted building, hereby request that you will arrange to supply me with water for domestic purposes in house No. ..... in ..... street. I am prepared to pay for the cost of the pipes required for the introduction of supply, and I herewith send Rs. 3 as a fee for the preparation of the estimate.

I also agree not to use water in excess of the quantity allowed by the council under section 147 (1) and, further, if I require water in addition thereto or for non-domestic purposes, to pay for such water at the rate of ..... annas per 1,000 gallons.

Countersignature of owner. Signature of $\frac{\text{owner}}{\text{occupier}}$.

The rules obtaining in Madras in regard to the laying of house service pipes by licensed plumbers are as below. These are followed by a specimen estimate such as these licensed plumbers prepare and obtain approval of before beginning work. That portion of the work up to the outer wall of the house or garden is usually executed by the municipal council at fixed rates :—

RULES REGARDING HOUSE SERVICE CONNECTIONS.

With reference to sections 141 and 213 of the Municipal Act I of 1884, in connection with a supply of water to houses for domestic, mechanical, ornamental or business purposes, the work within private lands or buildings shall be done by plumbers who have been found duly qualified, and who will be licensed annually after signing an agreement and paying a fee of Rs. 10 within the first month of each official year.

2. Each licensed plumber before the issue of the license shall be required to deposit with the Municipality the sum of Rs. 100 as a security for the due and proper fulfilment of a plumber's duties.

3. No person other than these plumbers will be allowed to execute any work in connection with water-supply to houses, &c.

4. If one or more plumbers form themselves into a company, any penalty exacted under these rules shall affect all plumbers belonging to such company.

5. A list of licensed plumbers shall be kept in the Municipal office and at the office of the Assistant Engineer, Water Works.

6. These plumbers will be empowered to carry out all private service pipe work, including new service pipes, extensions, alterations and repairs subject to the following rules, and to any reasonable orders given by the officers of the Water Works department from time to time.

7. When a new service pipe is required, the plumber selected by the applicant will present, at the office of the Assistant Engineer, Water Works, an estimate in duplicate approved of by the owner with a form of application requesting to sanction the work.

8. In such estimate shall be included the cost of the work on the roadways and streets, &c., between the Commissioners' main and the premises, including the tapping of the main, excavation in roadway, &c.; for such work, rates will be furnished by the Commissioners, and this work will be done by the Municipal Officers.

9. When the estimate has been sanctioned, the plumber, after receiving advice of the same, shall pay into the Revenue department of the Commissioners the cost of the work referred to in the last paragraph *plus* an amount equal to two per cent. (or such other percentage as may be fixed from time to time by the President) on the amount of the estimate, which percentage shall form portion of his estimate.

10. The plumber shall deposit all the material necessary for the work; after receipt of notice of such deposit the Municipality will within twenty-four hours inspect the material, and if the material is of the proper kind, the connection will be promptly proceeded with. After the Municipality have laid the necessary connection, an advice will be sent to the plumber that *his* work may be proceeded with.

11. Extensions, alterations and repairs shall be executed under a similar procedure in regard to the submission of estimate, payment of fees and execution of work. No new work, extension, alteration or repair shall be done except after the completion of the procedure required by the foregoing rules.

12. All plumbers shall keep a book to be provided by the Municipality in which shall be entered all details of works of every description whatsoever done by them in connection with any private service pipe. Such book shall be Municipal property and shall be sent to the Municipal office on the 15th of each month.

13. All repairs required under the Municipal Act by the President or authorized officers shall be done by such plumber as may be selected, the cost of such repairs will be recovered for the plumbers under the powers vested in the President by Act I of 1884.

14. All materials used or to be used and all work done shall be subject to the supervision, approval or rejection by the duly authorized officers of the Water Works department of the Municipality.

15. All cocks, taps and pipes shall be of a pattern or patterns which shall be kept at the Water Works overseers' offices and at the Municipal office.

16. No cock, tap, valve, sluice or other such fitting shall be used hereafter until approved of and stamped at the Municipal workshop with the municipal stamp for which a fee of annas two per article will be charged.

17. Whenever a plumber requires water to be shut off from, or let on to, any premises, he shall apply to the divisional overseer. No plumber shall interfere with any street stop-cock or stop-valve, all such stop-cocks or stop-valves being entirely under the control of the Commissioners.

18. The President may at any time fine, suspend or cancel with forfeiture of security the license granted to any plumber found guilty of breaking or evading any bye-law or other regulation of the Commissioners, or any of the foregoing rules, or who shall be guilty of any breach of the Municipal Act, or who fails to comply with any reasonable order given him by a duly authorized officer of the Water Works department or whose work in the opinion of the President is not satisfactory.

19. Any plumber whose license has been suspended or cancelled shall return his license to the President within twenty-four hours after such suspension or cancelment.

20. Any person who, without a license from the President or any plumber who during suspension or after cancelment of his license interferes with any work in connection with the water-supply will be prosecuted under section 222 of Act I of 1884.

MADRAS MUNICIPALITY.

WATER WORKS DEPARTMENT.

Plumber's Estimate.

For house service connection, extension or alteration, as per application for Mr. ..... house, No. ..... in ..... Street, ... Division ; Main 27″ diameter.

Quantity.	Particulars.	Rate.	Per	Amount.	Total.
		RS. A. P.		RS. A. P.	RS. A. P.
50	Feet of 1¼″ pipe, galvanized.	0 4 6	L.ft.	14 1 0	
50	Feet of 1″ pipe, galvanized.	0 3 6	do.	10 15 0	
1	1¼″ stop cock	6 0 0	Each.	6 0 0	
1	Cover for do.	1 4 0	do.	1 4 0	
3	1¼″ quarter bends, galvanized.	0 10 0	do.	1 14 0	
3	1″ quarter bends, galvanized.	0 8 0	do.	1 8 0	
1	1¼″ × 1″ tee, galvanized.	0 10 0	do.	0 10 0	
2	1″ × ½″ taper couplings ...	0 4 0	do.	0 8 0	
2	½″ discharge cocks ...	2 0 0	do.	4 0 0	
4	1¼″ and 1″ couplings ...	0 5 0	do.	1 4 0	
	Excavation inside compound 20 L. yds. of 1¼″ and 1″ pipe.	0 1 3	L.yd.	1 9 0	
	Laying and jointing 20 L. yds. of 1¼″ and 1″ pipe.	0 2 0	do.	2 8 0	
4	Cuts and screws on 1¼″ pipe.	0 10 0	Each.	2 8 0	
6	Cuts and screws on 1″ pipe.	0 8 0	do.	3 0 0	
					51 9 0
	Total ...	...	...	...	51 9 0
	MUNICIPAL WORK AT FIXED CHARGES.				
	Excavation in road way for 13 L.yds. of 1¼″ piping.	0 2 0	Inch L. yd.	2 0 6	
	Main, 27 inches	0 2 0	Inch.	3 6 0	
	For boring, tapping and cutting.	1 0 0	do.	1 4 0	

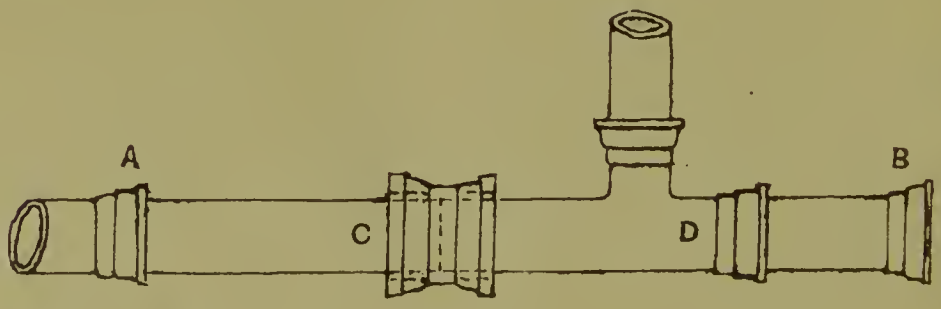
Quantity.	Particulars.	Rate.	Per	Amount.	Total.
N.B.—Payable to Revenue Department, Municipality.	MUNICIPAL WORKS AT FIXED CHARGES—*cont.*	RS. A. P.		RS. A. P.	RS. A. P.
	For fixing saddle or branch.	.....	...	.....	
	Do. valve	.....	...	.....	
	Do. stop cock 1¼".	0 2 0	Inch.	0 2 6	
	Laying and jointing, cutting and screwing 13 L. yds. of 1¼" piping.	0 1 0	Inch. L. yd.	1 0 3	
	Building up valves or stop cock and fixing cover.	0 8 0	Inch.	0 10 0	
	Total ...	.....	...	8 7 3	
	2 per cent. for supervision.	.....	...	1 3 2	
	Stamping charges for 3 discharge and stop cocks.	0 2 0	Each.	0 6 0	
					10 0 5
	Total ...	...	...	...	61 9 5

(Sd.) ....., *Licensed Plumber.*

I approve of this Estimate, and request it may be sanctioned.

MADRAS, *Date* ..... } (Signed) ....., *Owner or applicant.*

Insertion of branches.—When cast iron pipes are used for services, or other branch pipes and are connected with an existing main, special measures have to be taken. If the proposed branch pipe is only of slightly less diameter than the main from it is to draw its supply, it is desirable to cut out a portion of the main and put in a branch and for this purpose, what is known as a collar or sleeve, is required, thus—



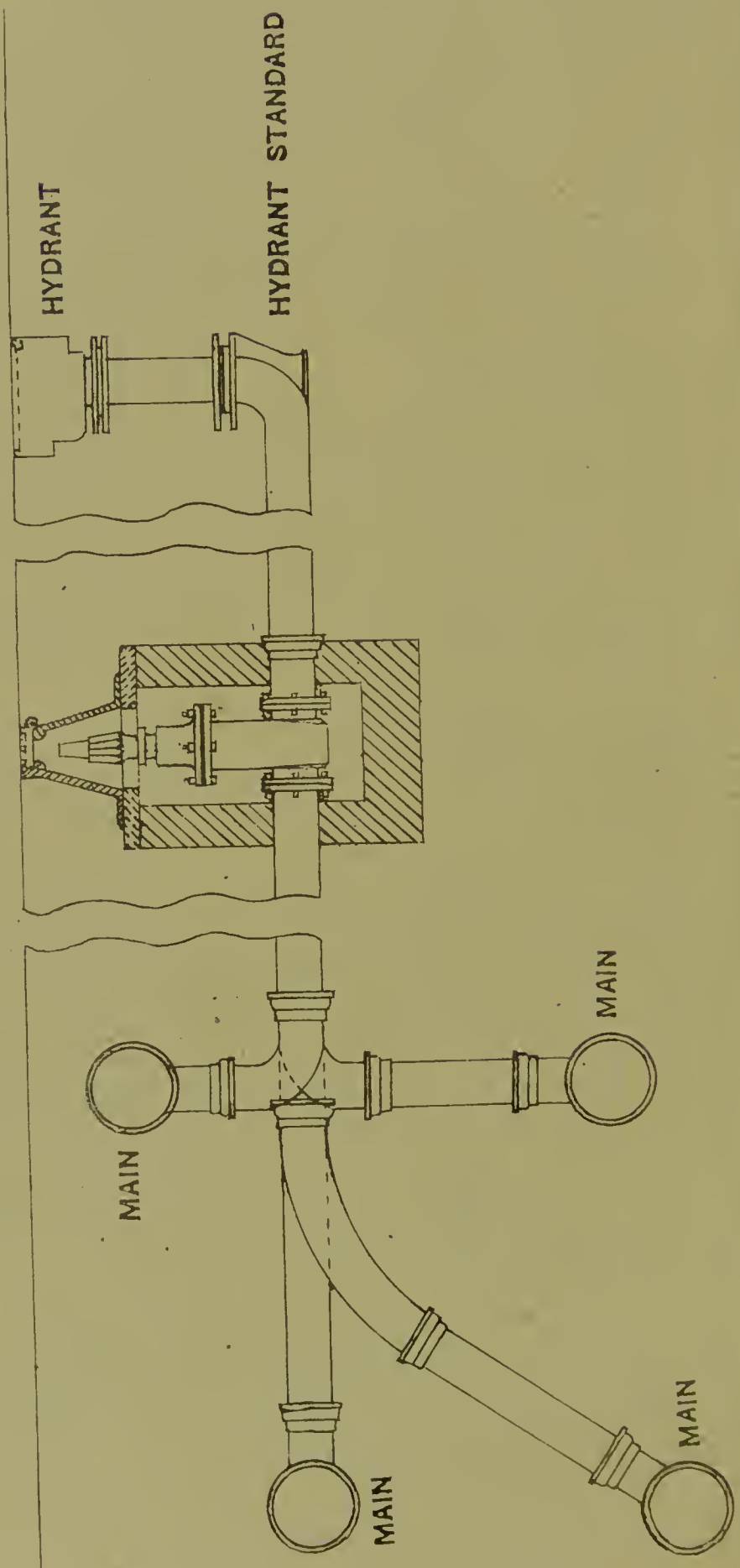
AB was the original pipe laid, the portion CD is cut out and the branch CD inserted, the joint C being made by a collar which is slipped on over the part C A and then brought into position when the branch has been inserted; a preferable plan is to place the branch so that the points D and B coincide and only one extra joint is then added to the pipe line instead of two.

The other method referred to, of joining a branch to an existing main is by means of what is known as a 'saddle.' This may be of either cast or wrought iron according to its size. In this method a hole is cut in the main pipe of the diameter of the branch pipe to be laid and the pipe is then jointed, all as illustrated.

It is well to avoid all such joints and wherever a branch is likely to be required, it is advisable to put in a branch pipe when laying the main and plug it until required.

Where the branch is to be of wrought iron and of small diameter compared with the main, a hole is tapped in the main and a ferrule inserted to which the branch is attached. There are several tools made for this purpose so that the ferrule can be inserted when the main is under pressure.

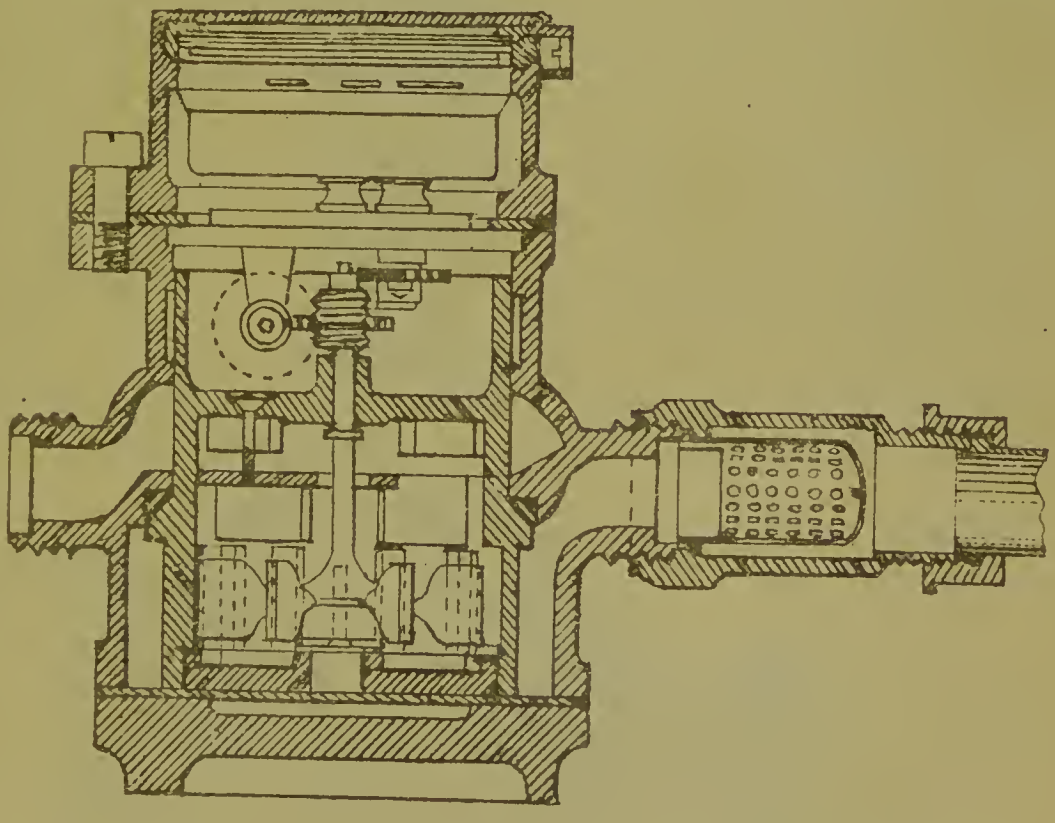
Branches to hydrants, &c.—Branch pipes may be taken from the main in several directions from the top, from the bottom or horizontally. It has been suggested that the depth at which the mains should be laid should not be less than 3 feet and so as to allow not less than 4 inches between the top of valve spindle and surface of road. These conditions may be modified to some extent, the mains being placed at such a depth below ground as will allow of the branch pipe being taken from the side or top of a main, the cover of any hydrants, air valves, &c., affixed to them being at road surface. The following diagram shows the various directions in which a branch may be laid to admit the top of the surface boxes of hydrants, air valves, &c., being at road surface level, or so that a service pipe may be run into a house at a certain depth below road level. Although the main pipe may be laid so as to have the valves on it arranged as above described, there may be undulations in the roadway, and at the site of a branch it may then be necessary to carry the branch at a much lower or higher level than the main. This and other circumstances decide which of the following methods should be adopted. The top of a main is the preferable position for an ordinary branch, scour pipes should always be taken from the bottom :—


HYDRANT
HYDRANT STANDARD
MAIN
MAIN
MAIN
MAIN

Prevention of waste.—The prevention of waste of water is one of the most difficult matters in regard to Indian water-supplies where such a very large proportion of the water is delivered at public fountains. The consumption by private houses which have gardens and for manufactures and trades is generally excessive, and all such service pipes ought to have a meter attached so that excessive consumption can be checked and a charge made.

A water meter is a somewhat expensive article, but it is generally found that its first cost is very soon repaid if it is applied with discretion.

The following meters are among those best known and their cost is as noted. Tylor's meter is illustrated below and Siemen's and Kent's in the diagram overleaf :—



Siemen's
Water meter
Section
Kent's
Section through centre of meters $\frac{3}{8}$" to 1" sizes

		Size of inlet and outlet in inches.													
		¾	½	¾	1	1¼	1½	2	2½	3	4	5	6	8	10	12
Siemen's meters.	Gallons per hour at a pressure of 50 ft.	150	300	600	1,500	2,200	3,000	4,000	6,000	8,300	13,400	18,500	27,000	45,000	70,000	90,000
	Gallons per hour at a pressure of 150 ft.	250	500	1,000	2,500	3,800	5,000	7,000	10,000	14,000	23,000	32,000	46,000	77,000	120,000	154,000
	Price ... ... *s.*	50	61	75	88	111	127	153	195	227	299	385	493	718	922	1,254
Kent's Positive meters.	Gallons per hour	1,200	1,600	3,500	5,000	...	8,500	12,000	...	21,000	30,000	...	70,000	...	...	...
	Price ... ... *s.*	75	85	105	140	...	210	300	...	560	800	...	1,200	2,000	3,000	3,900
Tylor and son's rotary meters.	Price ... ... *s.*	39	42	47	68	...	102	142	180	217	290	...	490	720	950	1,300
Beck and Co.'s positive meters.	Gallons per hour	...	...	1,400	2,500	...	4,500	8,000	...	11,000	...	...	...	...	...	...
	Price ... ... *s.*	...	...	175	241	...	385	678	...	812	...	...	...	...	...	...

N.B.—The prices are in shillings and are the prices in England.

COST OF WATER WORKS.

The cost of water-supply works naturally shows great variation not only in the total cost but as to the cost per head; the distance materials have to be transported, limited rainfall or the reverse, distance from a railway or canal, difficulties of transport and low exchange are all very serious factors in the cost; difficulties in execution, distance of a town from the gathering ground, costly labour, a small population or small density per acre on the town area are local circumstances affecting the cost and it is not, therefore, possible to say what the cost of a supply for any particular population will be; the following table gives information with reference to numerous towns for which water works have been constructed or are under construction; those towns marked * have not yet begun their projects, but the expenditure, as anticipated as shown, is taken from the estimates submitted to Government for their construction:—

Town.	Pumping or gravitation scheme.	With or without filter beds and service reservoir.	Population			Number of gallons and supply for which works are designed.		Number of gallons to be supplied at present.	
			Of whole town.	For which works are constructed.	To be supplied at present.	Total.	Per head.	Total.	Per head.
1	2	3	4	5	6	7	8	9	10
Madura	Pumping ...	Without filter bed or service reservoir.	87,426	100,000	80,000	1,500,000	15	1,200,000	15
Trichinopoly ...	Do. ...	Do. ...	88,715	88,000	70,466	1,320,000	15	1,057,000	15
Tanjore	Do. ...	Do. ...	54,055	60,000	48,000	900,000	15	720,000	15
Vellore * ...	Do. ...	Do. ...	44,950	50,000	44,950	750,000	15	674,250	15

Town.	Details of works.	Capital cost of works.	Rate of capital expenditure		Annual cost of maintenance.	Rate of maintenance		Remarks.
			Per head of population supplied.	Per 1,000 gallons to be supplied daily.		Per head of population supplied.	Per 1,000 gallons supplied daily.	
	11	12	13	14	15	16	17	18
		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
Madura ...	Head works ...	1,42,500	1·425	95·00	16,235	·20 or 3·2 As.	17·14	
	Distribution ...	2,81,860	2·818	187·90				
	Total ...	4,24,360	4·243	282·90				
Trichinopoly	Head works ...	1,84,700	2·098	139·92	29,295	·41 or 6·56 As.	27·61	
	Distribution ...	2,41,900	2·748	183·25				
	Total ...	4,26,600	4·846	323·17				
Tanjore ...	Head works ...	2,01,000	3·350	223·33	20,575	·42 or 6·75 As.	28·57	
	Distribution ...	2,28,000	3·800	253·33				
	Total ...	4,29,000	7·150	476·66				
Vellore * ...	Head works ...	1,57,205	3·145	209·60	17,758	·39 or 6·24 As.	26·34	
	Distribution ...	1,55,795	3·115	207·66				
	Total ...	3,13,000	6·260	417·26				

NOTE.—The capital cost is the cost per head for the total population for which the works are designed. The cost of maintenance is the cost due to pumping charges and repairs of the works only, and does not include interest on the capital cost.

Town.	Pumping or gravitation scheme.	With or without filter beds and service reservoir.	Population			Number of gallons and supply for which works are designed.		Number of gallons to be supplied at present.	
			Of whole town.	For which works are constructed.	To be supplied at present.	Total.	Per head.	Total.	Per head.
1	2	3	4	5	6	7	8	9	10
Coimbatore * ...	Pumping and gravitation.	With no filter beds, but with service reservoir.	46,362	52,000	46,362	780,000	15	695,430	15
Tuticorin * ...	Do. ...	With filter bed and service reservoir.	25,221	34,000	25,221	510,000	15	378,315	15
Dindigul ...	Pumping ...	Without filter bed, but with service reservoir.	16,000	22,000	16,000	220,000	10	80,000	5
Conjeeveram ...	Do. ...	Without filter bed or service reservoir.	46,362	56,000	46,362	840,000	15	463,620	10

Town.	Details of works.	Capital cost of works.	Rate of capital expenditure: Per head of population supplied.	Rate of capital expenditure: Per 1,000 gallons to be supplied daily.	Annual cost of maintenance.	Rate of maintenance: Per head of population supplied.	Rate of maintenance: Per 1,000 gallons supplied daily.	Remarks.
	11	12	13	14	15	16	17	18
Coimbatore*	Head works ...	Rs. 2,10,904	Rs. 4·056	Rs. 270·40	Rs. 20,900	Rs. ·45 or 7·2 As.	Rs. 30·07	Note.—The capital cost is the cost per head for the total population for which the works are designed. The cost of maintenance is the cost due to pumping charges and repairs of the works only, and does not include interest on the capital cost.
	Distribution ...	1,90,096	3·655	243·66				
	Total ...	4,01,000	7·711	514·06				
Tuticorin*	Head works ...	2,22,708	6·550	436·68	8,495	·33 or 5·28 As.	22·47	
	Distribution ...	96,002	2·823	188·20				
	Total ...	3,18,710	9·373	624·88				
Dindigul ...	Head works ...	42,600	1·936	193·640	5,020	·31 or 4·96 As.	62·75	
	Distribution ...	37,400	1·700	170·000				
	Total ...	80,000	3·636	363·640				
Conjeeveram	Head works ...	80,000	1·428	95·238	15,000	·32 or 5·12 As.	32·34	
	Distribution ...	1,90,000	3·393	226·190				
	Total ...	2,70,000	4·821	321·428				

Town.	Pumping or gravitation scheme.	With or without filter beds and service reservoir.	Population			Number of gallons and supply for which works are designed.		Number of gallons to be supplied at present.	
			Of whole town.	For which works are constructed.	To be supplied at present.	Total.	Per head.	Total.	Per head.
1	2	3	4	5	6	7	8	9	10
Adóni	Gravitation.	With filter bed and service reservoir.	26,212	30,000	26,212	300,000	10	262,120	10
Kurnool	Pumping and gravitation.	Do. ...	24,523	30,000	24,523	450,000	15	367,845	15
Dacca	.....	.....	82,321	.....	70,000	.....	.....	360,000	5·14
Burdwan ...	.....	.....	34,477	.....	21,000	.....	.....	180,000	8·57

Town.	Details of works.	Capital cost of works.	Rate of capital expenditure		Annual cost of maintenance.	Rate of maintenance		Remarks.
			Per head of population supplied.	Per 1,000 gallons to be supplied daily.		Per head of population supplied.	Per 1,000 gallons supplied daily.	
11		12	13	14	15	16	17	18
		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
Adóni ...	Head works ...	1,04,000	3·467	346·67	2,250	·08	8·58	NOTE.—The capital cost is the cost per head for the total population for which the works are designed. The cost of maintenance is the cost due to pumping charges and repairs of the works only, and does not include interest on the capital cost.
	Distribution ...	58,000	1·933	193·33		or 1·28 As.		
	Total ...	1,62,000	5·400	540·00				
Kurnool ...	Head works ...	1,25,060	4·168	277·91	7,800	·32	21·2	
	Distribution ...	97,380	3·246	216·40		or 5·1 As.		
	Total ...	2,22,440	7·414	491·31				
Dacca ...	Head works ...	2,48,580	3·552	691	13,586	·19	38	
	Distribution ...	1,08,750	1·552	302		or 1·04 As.		
	Total ...	3,57,330	5·104	993				
Burdwan ...	Head works ...	1,27,222	6·057	707	6,237	·29	35	
	Distribution ...	1,08,278	5·156	601		or 4·6 As.		
	Total ...	2,35,500	11·213	1,308				

Town.	Pumping or gravitation scheme.	With or without filter beds and service reservoir.	Population			Number of gallons and supply for which works are designed.		Number of gallons to be supplied at present.	
			Of whole town.	For which works are constructed.	To be supplied at present.	Total.	Per head.	Total.	Per head.
1	2	3	4	5	6	7	8	9	10
Bagalpur ...	.....	.....	69,106	.....	35,000	.....	.....	200,000	5·71
Darjeeling ...	.....	.....	17,000	.....	17,000	.....	.....	160,000	9·41

Town.	Details of works.	Capital cost of works.	Rate of capital expenditure.		Annual cost of maintenance.	Rate of maintenance		Remarks.
			Per head of population supplied.	Per 1,000 gallons to be supplied daily.		Per head of population supplied.	Per 1,000 gallons supplied daily.	
	11	12	13	14	15	16	17	18
		Rs.	Rs.	Rs.	Rs.	Rs.	Rs.	
Bagalpur ...	Head works ...	1,90,182	5·432	951	8,856	·25 or 4 As.	44	
	Distribution ...	1,11,675	3·192	558				
	Total ...	3,01,857	8·624	1,509				
Darjeeling.	Head works ...	43,080	2·531	269	3,671	·21 or 3·5 As.	23	
	Distribution ...	1,08,724	6·396	680				
	Total ...	1,51,804	8·927	949				

NOTE.—The capital cost is the cost per head for the total population for which the works are designed. The cost of maintenance is the cost due to pumping charges and repairs of the works only, and does not include interest on the capital cost.

It may be interesting to compare the cost of Indian water-supplies with those of England. Notwithstanding that the greater portion of the expenditure in Indian supplies is due to stores purchased in England, their cost per head of population is very much less, due probably in part to cheapness of labour and less perfection of distribution.

Table showing cost per head of some of the larger works per head of population.

——	Population.	Cost per head.
		£ s. d.
London	3,300,000	4 0 0
Liverpool	500,000	4 0 0
Bradford	150,000	7 0 0
Dundee	120,000	6 0 0
Cadiz	133,000	3 10 0

Table showing cost of Gravitation Works.

Name of town or district.	Population.	Maximum daily supply.	Constant or intermittent.	Total cost.	Cost for a supply of 20 gallons per day.
		GALS.		£	£
Aberdare ...	20,000	50,000	Constant.	20,000	8·00
Abergavenny ...	5,000	100,000		4,500	·90
Aylesbury ...	20,000	300,000		40,000	2·66
Ayr	16,000	600,000		41,000	1·36
Carnarvon ...	9,000	1,000,000		18,000	·36
Dumbarton ...	11,000	250,000		15,000	1·20
Dumfries ...	15,000	323,000		14,000	0·86
Gloucester ...	21,000	700,000		60,000	1·71
Hamilton ...	10,686	121,000		10,000	1·65
Heywood ...	30,000	700,000		80,000	2·28
Lancaster ...	16,000	750,000		40,000	1·07
Loughborough ...	12,000	300,000		25,000	1·66
Rochdale ...	38,164	600,000		74,494	2·48
Stirling ...	14,000	500,000		18,000	·72

Table showing cost of Pumping Works.

Name of town or district.	Population.	Maximum daily supply.	Constant or intermittent.	Total cost.	Cost for a supply of 20 gallons per day.
		GALS.		£	£
Banbury ...	6,000	24,000	Constant.	17,600	·91
Barnstaple ...	10,000	440,000		10,800	·49
Cambridge ...	30,000	417,000		48,000	2·30
Carlisle	29,000	1,000,000		44,000	·88
Cork	90,000	6,000,000		112,000	·37
Dorchester ...	7,000	960,000		13,000	0·27
Durham	20,000	260,000		20,000	1·54
Hereford ...	16,000	850,000		15,000	0·35
Inverness ...	12,000	360,000		13,000	·72
Newark-upon-Trent.	12,000	250,000		52,000	4·15
Ormskirk ...	6,000	250,000		10,000	0·80
Perth	24,000	600,000		19,000	0·63
Saffron Waldon ...	3,000	100,000		4,000	0·80
Southampton ...	54,000	3,000,000		50,000	0·33
Wallasey ...	15,000	800,000		44,000	1·10
Weymouth ...	12,000	600,000		18,000	·60
York	50,000	1,500,000		88,000	1·17

Table showing cost of Gravitation and Pumping Works.

Name of town or district.	Population.	Maximum daily supply.	Constant or intermittent.	Total cost.	Cost for a supply of 20 gallons per day.
		GALS.		£	£
Enfield	4,670	200,000	Constant.	17,500	1·75
Hartlepool ...	30,000	2,000,000		75,000	0·75
Kendal	13,000	300,000		15,500	1·03
Merthyr	55,000	1,500,000		84,000	1·12

An average, taken over 66 towns in Europe supplied by gravitation without pumping, showed the cost to be £1·6 for a supply of 20 gallons per head daily, and an average over 11 towns with gravitation and pumping works showed an expenditure of £1·4 per head. The cost of the Calcutta works was about £1·77 (before the new main lately constructed was laid down); and the Madras works, it is expected when complete, will cost £1·37 per head. The cheapness of labour in this country compensates for the very heavy charges connected with the conveyance to this country of iron pipes, fittings, &c.

The following further details of the cost of several portions of water-supplies will be found useful:—

Table showing number of gallons per square yard and cost per square yard of open filter beds.

Place.	—	Population.	Gallons per diem.	Number of beds.	Area of beds, square yards.	Number of beds to be ordinarily in use.	Area of beds to be in use, square yards.	Number of persons per square yard of filter (Col. 8).	Number of gallons to be filtered per square yard in 24 hours.	Cost.	Cost per square yard (Col. 6).	Cost of beds per 1,000 gallons filtered daily.
1	2	3	4	5	6	7	8	9	10	11	12	13
										RS.	RS.	RS.
Ádóni	Constructed ...	30,000	300,000	3	667	2	445	67·41	674·16	14,215	21·31	47·38
Kurnool	Under construction.	30,000	450,000	4	1,112	3	834	35·97	539·56	21,154	19·02	47·01
Cocanada	Designed ...	50,000	750,000	4	1,778	3	1,333	37·51	562·64	43,139	24·26	57·52
Tuticorin	Sanctioned ...	34,000	510,000	4	1,244	3	933	36·44	546·62	32,886	26·43	64·48
Vizagapatam ...	Designed ...	40,000	600,000	3	1,693	2	1,129	35·43	531·44	21,910	12·94	36·52
Peshawar	Constructed ...	...	...	3	891	...	...	...	...	26,956	30·25	...

NOTE.—The cost of English filter beds (open) including appliances is between *s.* 33/5 and *s.* 41/9 per square yard. Filtration costs *s.* 34/to *s.* 56/8 per million gallons, of this sum 50 to 60 per cent. represents interest and sinking fund and 40 to 50 per cent. wages.

Table showing cost per cubic foot of capacity of covered service reservoirs in certain towns, the works of which are either constructed, sanctioned or designed.

Place.	—	Population.	Capacity in cubic feet per 1,000 of population.	Capacity of reservoir in cubic feet	Cost.	Cost per cubic foot of capacity.	Cost per 1,000 gallons stored.	Cost per 1,000 people.
1	2	3	4	5	6	7	8	9
					RS.	RS.	RS.	RS.
Ádóni	Constructed	30,000	1250·00	37,500	15,320	·409	65·36	510·66
Bezwada	Designed	28,000	1719·00	48,132	15,800	·328	52·52	564·29
Cuddalore	Approved	50,000	1804·36	90,218	15,570	·173	27·61	311·40
Cocanada	Designed	50,000	1606·72	80,336	32,144	·400	64·00	642·88
Cuddapah	Constructed	20,000	1543·75	30,875	9,094	·294	47·12	454·70
Coimbatore	Designed	52,000	1960·00	101,920	37,439	·367	58·77	719·98
Dindigul	Constructed	16,000	880·06	14,081	8,330	·591	94·65	520·62
Kurnool	Under construction ...	30,000	1666·00	49,980	15,070	·302	51·54	502·33
Tuticorin	Sanctioned	34,000	1752·94	59,600	26,219	·440	70·40	771·15
Vizagapatam ...	Designed	40,000	2675·25	107,010	18,460	·172	27·61	461·50

APPENDIX TO CHAPTER No. VII.

RULES FOR STARTING AND WORKING FILTERS.

Starting filters.—The filters are supposed to be free from water, as they will be after thorough cleaning or when used for the first time. Under these circumstances it is desirable to begin the filling from the bottom, if possible, and, where the service reservoir is adjacent to the filter bed, that reservoir should be partly filled with water (unfiltered water will have to be used if the filters are being started for the first time) and the water passed from the service reservoir to the filters. For this purpose the telescopic regulating pipes of the filter outlets should be lowered to their full extent. The valve between the filters and reservoir should be regulated so that, after the water reaches the level of the top of the telescopic pipe, the supply to the filters is such that the water does not rise more than 4″ per hour; the water must be allowed to rise until it stands at a height of 6″ over the top of sand. The number of hours the filter will take to fill depends on the height in inches which the surface of the sand is above the floor plus 6″, divided by 4, thus if the sand is 5′—0″, or 60″ above the floor, then $\frac{60'' + 6''}{4} = 16$ hours—30 minutes. If the rate exceeds this, the sand will be disturbed and this must never be allowed to occur. The remaining depth of water over the sand, ordinarily (3′—0″) —(0′—6″) =2′—6″, may be filled through the valves which will be used daily for supplying the filters, but at the same rate as before until a height of 1′—6″ is attained abcve sand level; after this the remaining 1′—6″ may be filled at a higher speed.

Process of filtering.—A filter bed filled as above should not be used, but should be left standing full of water (the outlet valves being closed and the telescopic outlet pipes being raised to their full height) until after the expiry of 24 hours. The working of the filters may then be begun. To do so, the telescopic pipe should be gradually lowered until there is a slight flow of water from the filter, and this lowering shall be very slowly increased until the water from the filter is passing through it at the rate of 4″ in depth per hour. This flow, it is impossible to determine from observations at the filter itself, or from any service reservoir which is itself being drawn off. It cannot be determined from the filter bed, because the inlet valve

to the filter bed should be so regulated that the depth of water over the sand is maintained at *three feet* except when emptying a filter, the *rate* of filtration being entirely dependent on the lowering of the telescopic pipe outside the filter. If the service reservoir into which the filtered water is passing is *not* being drawn from, then the rate can be determined thus; the rise in the service reservoir is in the inverse proportion to 4″ as the area of the filter bed at the water level is to the area of the reservoir at its water level; thus, if the area of the filter bed is twice the area of the service reservoir, then the rise must be $2 \times 4'' = 8''$ per hour in the service reservoir. To determine the rate of flow through a filter bed, the outlet valve of the service reservoir into which it is discharging may be shut off for half an hour, and the rise of surface in the reservoir measured.

Telescopic pipes are sometimes furnished with a guage rod, and if the depth of water flowing over top of pipe be noted and the circumference of the pipe taken as the length of a weir by determining a proper co-efficient, the flow can be approximately calculated.

To maintain the same rate of flow (because as filtration goes on the filter gets more foul and organic matter will have collected and closed up the pores in the sand), the filtering head of water will have to be gradually increased; this is done by lowering the telescopic valves outside the filter. The head of three feet depth of water over the sand surface is never to be increased or diminished and has no influence whatever on the rate of filtration. The telescopic pipe must be lowered and the filter head increased *very gradually*. Any *sudden* fluctuation of head is to be avoided. When the proper rate of flow has again been attained, the filter will be allowed to discharge under that head until a further increase of filter head is necessary.

But the filter head, that is, the difference of level between the surface of the water in the filters and the level of the surface of the water flowing over the top of telescopic pipe must never exceed 2′—0″; and when (or before) this limit is reached the filter bed must be put out of use and cleaned. It may sometimes be necessary to clean a filter bed before the limit is reached, as, after a filter has been some weeks in action, especially in hot weather, organic matter collects on the surface, which matter will die and putrefy. As soon, therefore, as spongy particles, or masses of organic matter, shew on the surface, a filter must be put out of action.

Emptying and cleansing.—For the purpose of ordinary cleansing, the water will be run into the service reservoir until it is drawn down to the level of the sand. This is done *not* by altering the rate of flow but by closing the valve of the inlet pipe to the filter bed and lowering gradually the telescopic

pipe so that the depth of flow over its mouth is not increased. When the water has been lowered to sand level, the scour valve of the filter bed should then be opened and the water lowered until it stands one foot below the surface of the sand, or more if the sand is not in a fit condition for workmen to move over it without injuring its compact surface and sinking into it. Workmen must then with wooden shovels carefully remove a depth of sand not exceeding *one half* inch in thickness. The sand so removed must be taken away and deposited near the sand-washing box. After that depth of sand has been carefully removed, the sand surface must be carefully raked with (so called) wooden rakes without teeth, until the surface is perfectly level again. The filter should then be left exposed for 24 hours at least, before water is filled into it again; this must be done as before until the water rises to a level of .6″ above the sand in the manner already described. When it is necessary to clean the side walls of a filter, this may be done from a raft, before the filter is emptied and the water in the filter used for the purpose; but in such case all the water in the filter must be then emptied through the scour valve.

Renewal of sand.—The sand taken from the filter is not to be replaced until *one foot in thickness* of the sand has been removed, therefore not until the sand surface has been scraped 24 times will it be necessary to replace the sand.

Washing of sand.—The sand removed from the filters shall be thoroughly washed in the sand-washing box. The box must be almost filled and water let in under the sand with a pressure of about 7 to 8 feet of water. The sand must be stirred about until the effluent water is perfectly clear. It is necessary that the sand should be washed *immediately it is removed from the filters* and *not* just before it is to be replaced. Fine sand is likely to be run out with the impurities from the sand and it is therefore very necessary to see that this is arrested and not allowed to choke the waste water culvert. The sand must be so thoroughly washed that, when a sample is placed in a tumbler of water and stirred, it does not shew any turbidity.

When the sand has been washed, it should be thrown into heaps in one corner of the filter bed.

The replacing of the sand should be done after emptying the filter; the sand must be thoroughly tamped and levelled and the filter then refilled as already described.

CHAPTER VIII.

DRAINAGE.

No rules universally applicable to sewerage works.—The construction of conduits for sewage or sewers falls specially within the province of an Engineer, but it may be taken as an ascertained fact that no abstract rules universally applicable can be laid down for his guidance in the prosecution of works of sewerage, though there are some general principles common to all such works.

Requirements of sewage works.—Local conditions and requirements must influence an Engineer in deciding upon the main feature of any sewage scheme. In all cases, however, it is the first requirement that the works as constructed must fulfil their sanitary mission and the second, that the profitable disposal of the matters dealt with, though a point of minor importance, should not be lost sight of.

Preliminary steps necessary.—The works for the drainage of a town comprise those necessary for carrying off (1) surface water, (2) fæcal and liquid refuse, (3) sub-soil water; and before any design can be prepared, inquiries on the following points are necessary, viz. :—

(1) The area of the district to be served.

(2) The geological character and physical outline of the district.

(3) The amount of rainfall, and the proportion to be permitted to enter the sewers.

(4) The present population and rate of increase.

(5) The amount of the water-supply.

(6) The position of the outfall.

(7) The position and size of any existing sewers, channels or water-courses.

(8) The existing mode of disposing of sewage, fæcal matters, &c.

(9) Information should also be obtained as to the prevailing winds, the heaviest known rainfalls, and, if the town is near the sea and the outfall is proposed to be into the sea, as to the currents passing up and down the coast at various times of the year and as to any erosion or accretion taking place on the sea shore.

Plans required.—The following plans should then be prepared :—

(1) A small plan, on a scale of not less than 6 inches to a mile, of the area to be drained, showing the lines of existing and proposed main sewers.

(2) Larger plans to a scale, say, of 200 feet to the inch, showing the exact lines of the sewers, drains, &c., proposed, with the position of the outfall and with the levels marked on at street-crossings, at summits and in valleys.

(3) A plan, to a scale of 30 to 60 feet to 1 inch, of the main streets in which sewers are to be laid.

(4) Sections of the lines of the sewers to scales of not less than 100 feet to an inch horizontal and 10 feet to an inch vertical, noting the levels of the lowest floors of the adjacent houses.

When the above plans have been completed, and the main lines on which the works are to be constructed have been decided upon, the preparation of detailed plans and estimates should then be commenced, and in these designs the principles hereinafter stated ought to be observed as far as possible.

WATER CARRIAGE SYSTEM (DESIGN).

Water carriage system.—Many systems for the carriage of town sewage have been proposed; but of all these the water carriage system is the best adapted to the varied requirements of a town population, and to this system the following pages have reference.

Admission of rainfall to sewers.—Where the rainfall is moderate, there is great difference of opinion as to whether or not rain ought to be admitted into the sewers, but where suitable natural outlets for rainfall exist, it is, of course, more economical to design the sewers and drains to carry off sewage alone.

Separate system preferable.—That system is known as the separate system, and is preferable to the combined system in which the sewers carry off both storm-waters and sewage. Where proper outlets do not exist for storm-waters, or where these flow on to lands which thereby become swampy or marshy, or where the storm-waters are so filthy as to pollute any stream into which they may flow, the adoption of the combined system is advisable.

Intermediate system.—There is what may be called the intermediate system in which a portion only of the rainfall is admitted into the sewers. This is for the reason that a rainfall of small amount, or the first portion of the discharge from a heavy rainfall, is generally loaded with impurities, while the water afterwards contributed is comparatively pure.

Under Indian conditions two sets of sewers advisable.—In countries, such as India, where there are distinct periods of wet and drought, it is generally desirable to convey away the excessive storm-water by a distinct set of sewers or by natural outlets, while the sewage proper is conveyed away by a second set. The reasons for this are obvious; owing to the large amounts of rain received in short periods, sewers or conduits, for conveying away sewage combined with storm-water, would be so out of proportion to the work they would ordinarily have to do, viz., the conveyance of sewage alone, that they would be sewers of deposit and become a danger to public health, and, because of the storage room such sewers would afford for gases evolved from the sewage, these gases, on occasions of rainfall, would be forced out of the sewers in large volumes; where the contents of sewers would have to be pumped out, it would be necessary to provide a large reserve of machinery and to keep it always ready for disposing of the storm-waters; this would form a considerable additional item of expenditure.

Rainfall discharge.—As has been pointed out in connection with 'water-supply,' the discharge from any area will be somewhat less than the amount of fall as indicated by a rain gauge, and during the heavier falls the proportionate discharge will be greater than during falls of less intensity. Therefore, even in the combined system, it is usual to fix on a maximum rainfall per hour to be carried off by the sewers to their outfall, any further amount being disposed of at storm-water overflows into natural channels.

The following table will be found useful in making calculations for the amount falling on any given drainage area:—

Table showing the quantity of Rainfall per acre.

Inches in depth of rain.	Cubic feet per acre.	Gallons per acre.	Inches in depth of rain.	Cubic feet per acre.	Gallons per acre.
·1	363	2,262	·6	2,178	13,573
·15	544·5	3,393	·65	2,359·5	14,704
·2	726	4,524	·7	2,541	15,836
·25	907·5	5,656	·75	2,722·5	16,967
·3	1,089	6,787	·8	2,904	18,098
·35	1,270·5	7,918	·85	3,085·5	19,309
·4	1,452	9,049	·9	3,267	20,360
·45	1,633·5	10,180	·95	3,448·5	21,491
·5	1,815	11,311	1·0	3,630	22,622
·55	1,996·5	12,442			

Rainfall discharges with reference to the physical character of an area.—The physical outline of a district will have a material effect on the quantity of water conveyed to the sewers, as, where the area to be drained is of considerable declivity, the flow during rainfall will be greater than from areas where less steep gradients prevail.

Geology of drainage area to be considered.—The geological character and physical outline of a district are points on which information should be carefully obtained, especially in reference to the depth of the various strata underlying the town, the depth at which rock or other hard stratum is met with, and the level of the subsoil water during the various seasons of the year.

Arrangements to admit subsoil water to sewers not desirable.—As has been already pointed out, sudden variations in the level of subsoil water are apt to be followed by outbreaks of disease, and therefore in many sewerage systems distinct provision is made for the drainage of the subsoil. It is not a good plan to make special provision for subsoil water entering a sewer, for if that be done, unless there is a great depth of subsoil water over the sewer, it affords an unnecessary facility for the sewage to pass into the soil. It is in porous soils extremely difficult to keep subsoil water out of the sewers, and sewers, made of the best pressed bricks with the strongest cement, which are below subsoil water level, will be found to have a flow of water in them before any sewage is admitted.*

Subsoil drainage. — A good plan for the drainage of the subsoil is to embed the sewers in clay, and then to fill the trenches for some 3 or 4 feet above them with clean gravel or sharp sand; in such cases, however, the trenches must be carried on to some place where they will have a clear outfall.

Statistics of population. — As to the population, statistics within the last ten years will be usually available, and a reference to previous census reports will enable the prospective increase of population to be gauged; *vide* Vital Statistics.

Calculation of population per lineal foot of street desirable.—It is advisable, when designing drainage works,

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* NOTE.—In wet soil, the leakage into pipe sewers will amount to not less than 1 cubic foot per minute per mile. It is calculated that one drop of water per second from each pipe joint will amount to ¼ cubic foot per minute per mile.

to find out the number of persons residing in a certain length of street, say 50 feet, and therefore the population of certain typical streets should be ascertained, and the number of persons per 50 feet of street calculated. Certain areas of a town will be more densely populated than other areas, and the streets selected as typical should be from among those passing through areas having very varied densities of population. The density of the population affects the dimensions of the various portions of sewerage works, because, for the purposes of design, it is usual to suppose that each person uses a certain number of gallons of water for ablution and other domestic purposes, and also contributes a certain amount of solid or liquid excrementitious matter to the sewers.

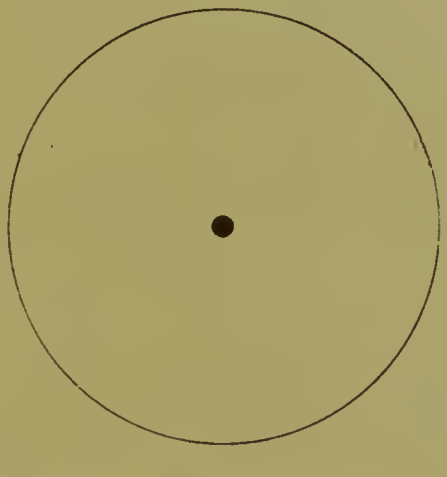
How to determine quantity of fluid matter to be dealt with.—The quantity of fluid matter which the sewers should be designed to carry off must be considered, *firstly*, in relation to the amount of the water-supply from any water works; *secondly*, in regard to water drawn from tanks, wells, &c.; *thirdly*, in regard to the amount of rainfall, if any, to be admitted to the sewers. The maximum hourly discharge should, if possible, be ascertained, and it should also be determined whether there are extraordinary variations in flow on different days in the week. Temperature affects the flow to a considerable extent, thus hot weather might increase the water consumption and waste to a greater extent than any extra amount which could, in a well designed separate system, pass into the sewers during rainfall.

English allowance.—In England, in towns where perfect systems of water-supply exist, the average quantity allowed for, is 25 gallons per head per 24 hours, half that quantity passing off in six hours; the sewers have, therefore, a capacity sufficient to carry off 50 gallons per head of population in 24 hours. In England, however, the majority of the towns have large manufactories, the houses are in general provided with water closets requiring large quantities of water, and all waste water generally falls into sinks or on to paved surfaces, whence it flows direct to the sewers.

Indian requirements.—In India, few, except the large, towns use water to any great extent in manufactures; water closets are almost unknown, and not likely to become popular, and a much smaller proportion of the water used flows off into the drains; taking all these circumstances into consideration, it is probable that an allowance of 15 gallons per head,

one-half flowing off in 6 hours or 30 gallons per head per 24 hours will, for most towns, be found sufficient.

Admission of fæcal matters to sewers.—Whether fæcal matters are or are not admitted into the sewers is, as to the volume to be carried, a matter of little importance. Taking 30 gallons per head as the amount to be carried away, and looking at the following diagram, where the space enclosed by the outer circle represents that total, and the inner dot the comparative quantity of solid and fluid fæcal matter per head to be dealt with, it will be observed that the latter quantity is extremely insignificant :—



Main points to be observed in sewer design and construction.—Some of the main points to be observed in designing sewers are these :—

(1) The sectional area and gradient of a sewer must be regulated so as to make it self-cleansing, and, at the same time, capable of carrying off effectively the maximum quantity of liquid for which it is intended.

(2) Each sewer (unless quite impracticable) should be laid in straight lines with even gradients between man-holes or lamp-holes, and these gradients must not be excessive, that is, they must not be such as will make the velocity of flow in excess of 6 feet per second.

(3) Man-holes and lamp-holes should be of the most simple construction, and their design suited to the material to be used ; they may also be made to act as flushing or ventilating chambers, junction shafts, &c.

(4) Tributary sewers ought not to join at right angles, but be inclined towards the direction of the flow of main

sewers, and they should join at a height equal to the difference of the sectional diameters.

(5) The sectional area of each sewer ought to be as small as possible with reference to the work which it has to do; pipe sewers ought not to be less than 6 inches in diameter.

(6) Stone-ware pipes of greater diameter than 18 inches ought not to be used; brickwork or concrete ought to be employed for sewers above that dimension.

Position of sewer outfalls.—The position of the outfall of a sewer is of great importance. In general, the fall of the sewers should follow the natural fall of the district; but this, in some cases, may be impractical or injudicious. Sewers should, in no case, be discharged into any natural stream, nor into the sea where the currents are such as would wash the sewage back on to the shore, or up and down the coast opposite the town.

Indian climate suitable for sewage farming.—The climate of this country is eminently fitted for the working of sewage farms, and it is therefore advisable to dispose, when possible, of all sewage on to land; what is called the intermittent system of irrigation, which will hereafter be described, is the most suitable for adoption. In such a design it is a necessity that the sewage farm should be on that side of the town opposite to the quarter whence the prevailing winds blow.

Old forms of sewers.—Sewers were, until of late years, always constructed of such a size that men might enter them to clean them out, and they were usually square in section, or approaching that form; some had rounded bottoms, some arched tops, but all were generally too large for the work to be done.

Sewers to be designed with regard to the work to be done.—As previously observed, sewers and drains must be designed of such size and dimension as will accord with the work they have to do, and they must not be made larger than this work requires. Sewers will always be self-cleansing, when their size, form and inclination are proportionate to the volume of sewage to be conveyed.

Prevention of deposit.—In order to prevent deposit in sewers, it is necessary to ensure a certain velocity in the flow of sewage, and this must be secured throughout the whole system of sewers; such velocity must be sufficient

to prevent the subsidence of any matters in suspension and also to move along the bed of the channel any solid deposit. Under any circumstances the velocity of a sewer should not be less than 2 feet per second. The velocity required to move certain substances is as under :—

	Per second. FT.	IN.
Semi-fluid mud	0	3
Common clay	0	6
River sand	1	0
Gravel size of beans	1	0½
Sea shingle about 1 inch diameter ..	2	2
Broken stones	4	0

Rankine's rules for velocities of flow.—Professor Rankine has laid it down as a rule that the velocity in sewers should not be more than 4½ feet per second nor less than 1 foot per second. In smaller sewers, however, the velocity ought to be proportionally greater, thus, while sewers 12 to 24 inches diameter may be designed for a velocity of, say, 2 or 2½ feet per second, a drain 6 inches or 9 inches in diameter should have a velocity of, probably, not less than 3 feet per second.

Maximum and minimum velocities.—When the quantity of sewage flowing in a sewer is likely to vary, it is, of course, necessary to ensure the minimum velocity when only the minimum quantity is flowing. Sewers of different sizes may have the same velocity of flow ; thus the following sewers, viz., those of

10 feet	diameter,	2 feet	fall	per mile.
5 do.	do.	4	do.	do.
2 do.	do.	10	do.	do.
1 foot	do.	20	do.	do.

will all have the same velocity, but, in order to *maintain* the same velocity, the volume of flow must be in the following ratio :—

	Ratio.
10 feet sewer	100
5 do.	25
2 do.	4
1 foot sewer	1

The following tables, extracted from Baldwin Latham's "Sanitary Engineering," show (1) the proper inclination of circular sewers for securing various velocities, (2) the velocities in circular sewers with various rates of inclination :—

(1) *Table showing the proper inclination for circular sewers for securing various velocities (feet per second).*

Diameter in inches.	Rate of inclination for					
	V = 2	V = 2·5	V = 3	V = 3·5	V = 4	V = 4·5
3	1 in 146	1 in 97	1 in 69	1 in 51	1 in 40	1 in 32
4	1 in 194	1 in 129	1 in 92	1 in 68	1 in 53	1 in 42
6	1 in 292	1 in 193	1 in 137	1 in 102	1 in 80	1 in 63
8	1 in 389	1 in 257	1 in 183	1 in 137	1 in 106	1 in 85
9	1 in 437	1 in 290	1 in 206	1 in 154	1 in 119	1 in 95
10	1 in 486	1 in 322	1 in 229	1 in 171	1 in 133	1 in 106
12	1 in 583	1 in 386	1 in 275	1 in 205	1 in 159	1 in 127
14	1 in 681	1 in 450	1 in 321	1 in 239	1 in 186	1 in 148
15	1 in 729	1 in 482	1 in 344	1 in 256	1 in 199	1 in 159
16	1 in 778	1 in 515	1 in 367	1 in 273	1 in 212	1 in 169
18	1 in 875	1 in 579	1 in 412	1 in 307	1 in 239	1 in 190
20	1 in 972	1 in 643	1 in 458	1 in 342	1 in 265	1 in 212
21	1 in 1,021	1 in 676	1 in 481	1 in 359	1 in 278	1 in 223
22	1 in 1,069	1 in 708	1 in 504	1 in 376	1 in 292	1 in 233
24	1 in 1,166	1 in 772	1 in 550	1 in 410	1 in 318	1 in 254
27	1 in 1,312	1 in 869	1 in 619	1 in 461	1 in 358	1 in 286
30	1 in 1,458	1 in 965	1 in 687	1 in 512	1 in 398	1 in 317
33	1 in 1,604	1 in 1,062	1 in 756	1 in 564	1 in 438	1 in 349
36	1 in 1,749	1 in 1,158	1 in 825	1 in 615	1 in 477	1 in 381
40	1 in 1,944	1 in 1,286	1 in 917	1 in 683	1 in 530	1 in 423
42	1 in 2,041	1 in 1,351	1 in 962	1 in 718	1 in 557	1 in 445
45	1 in 2,186	1 in 1,448	1 in 1,031	1 in 769	1 in 596	1 in 476
48	1 in 2,332	1 in 1,544	1 in 1,100	1 in 820	1 in 636	1 in 508
54	1 in 2,624	1 in 1,737	1 in 1,237	1 in 922	1 in 716	1 in 571
60	1 in 2,915	1 in 1,930	1 in 1,375	1 in 1,025	1 in 795	1 in 635

(2) *Table showing the velocities in circular sewers (feet per minute) when running full or half full at various rates of inclination.*

Rate of inclination.	Size.													
	d=6″	d=9″	d=12″	d=15″	d=18″	d=21″	d=24″	d=27″	d=30″	d=36″	d=42″	d=48″	d=54″	d=60″
1 in 20	481	582	664	734	794	848	896							
1 in 25	432	525	600	664	720	771	816							
1 in 30	395	481	551	611	664	711	755							
1 in 35	366	446	513	569	619	664	705							
1 in 40	342	418	481	535	582	625	664							
1 in 45	322	395	454	506	551	592	630							
1 in 50	307	375	432	481	525	564	600							
1 in 60	279	343	395	440	481	517	551							
1 in 70	257	317	366	408	446	481	513							
1 in 80	239	296	342	382	418	451	481							
1 in 90	225	279	322	360	394	426	454							
1 in 100	213	264	306	342	374	404	432	457	481	525	564	600	633	664
1 in 110	202	251	291	326	357	386	413	436	459	501	539	574	606	636
1 in 120	193	240	278	312	342	369	395	418	440	481	517	551	582	611
1 in 130	186	230	267	299	328	355	379	401	423	463	498	531	561	589
1 in 140	178	221	257	288	316	342	365	387	408	446	481	513	542	569
1 in 150	172	213	248	278	306	330	353	374	395	432	465	496	525	551
1 in 160	166	206	240	269	296	320	342	362	382	418	451	481	509	535
1 in 170	160	199	232	261	287	310	332	352	371	406	438	467	494	520
1 in 180	155	193	225	253	278	301	322	342	361	395	426	454	481	506
1 in 190	151	188	219	246	270	293	313	333	351	384	415	442	468	493
1 in 200	147	183	213	239	263	285	305	324	342	375	404	431	457	481
1 in 250	131	163	189	213	234	254	272	290	305	335	362	387	411	433
1 in 300	118	147	172	193	213	231	248	264	278	305	330	353	375	395
1 in 350		135	158	178	196	213	228	243	256	282	306	327	347	366
1 ln 400		126	147	166	183	199	213	226	239	263	285	306	325	342
1 in 450		118	138	156	172	187	200	213	225	247	268	289	307	323
1 in 500			130	147	162	177	189	202	213	234	254	273	290	306
1 in 550			124	140	154	168	180	192	203	223	242	260	276	291

(2) *Table showing the velocities in circular sewers (feet per minute) when running full or half full at various rates of inclination*—cont.

Rate of inclination.	Size.													
	d=6″	d=9″	d=12″	d=15″	d=18″	d=21″	d=24″	d=27″	d=30″	d=36″	d=42″	d=48″	d=54″	d=60″
1 in 600			118	134	147	160	172	183	194	213	231	248	263	278
1 in 650				128	141	153	165	175	186	204	222	238	252	267
1 in 700				123	135	147	158	168	179	196	213	229	243	257
1 in 750				118	130	142	152	162	172	189	205	221	235	248
1 in 800					126	137	147	157	166	183	199	213	226	239
1 in 850					122	133	142	152	161	177	193	206	219	231
1 in 900					118	129	138	147	156	172	187	200	213	225
1 in 950						125	134	143	151	167	181	195	207	219
1 in 1000						121	130	139	147	162	176	190	202	213
1 in 1100							124	132	140	154	168	181	192	203
1 in 1200							118	126	133	147	160	172	183	193
1 in 1300								120	127	141	153	165	175	185
1 in 1400									122	135	147	158	168	178
1 in 1500									118	130	142	152	162	172
1 in 1600										126	137	147	157	166
1 in 1700										122	133	142	152	161
1 in 1800										118	129	138	147	156
1 in 1900											125	134	143	151
1 in 2000											121	130	139	147
1 in 2100												127	135	143
1 in 2200												124	132	140
1 in 2300												121	129	136
1 in 2400												118	126	133
1 in 2500													123	130
1 in 2600													120	128
1 in 2700													118	125
1 in 2800														123
1 in 2900														120
1 in 3000														118

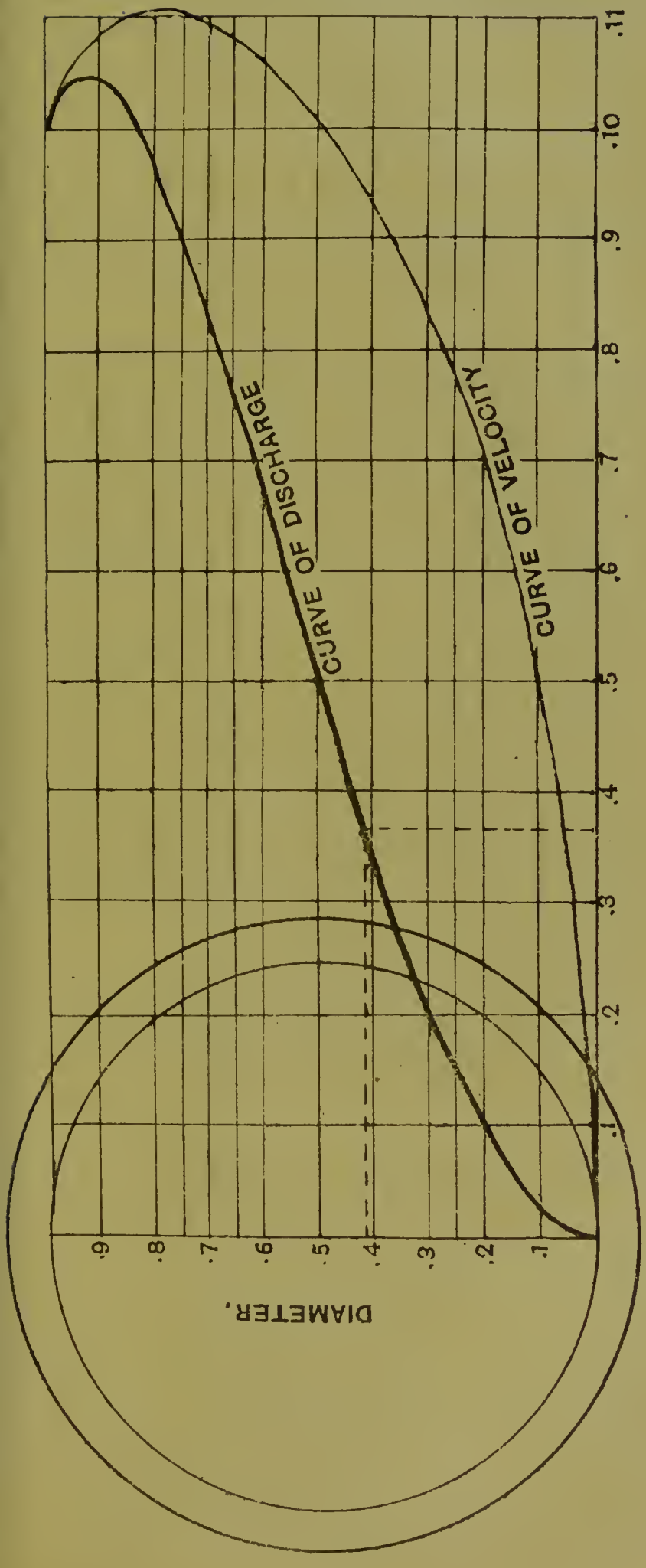


DIAGRAM SHOWING COMPARATIVE VELOCITY AND DISCHARGE IN CIRCULAR SEWERS OF A GIVEN DIAMETER AND GRADE, FOR VARIOUS DEPTHS OF FLOW.

Velocities in channels.—The velocity in feet per second of water flowing in a channel may be found by the formula—

$$V = 9 \cdot \sqrt{2F\frac{A}{B}}$$

where F = fall in feet per mile and $\frac{A}{B}$ is the H M D; this will be found a useful formula for calculating sewer velocities, because sewers do not always run full, as water pipes under pressure do.

The diagram on the preceding page affords a convenient method of computing the discharge of a circular sewer at any depth. The calculation may be made as follows:—Divide the depth of flow by the diameter, and from that fractional depth, thus indicated on the vertical diameter, draw a horizontal line intersecting the curve of discharge and from this latter point a vertical line to the base. The percentage indicated on the base will be the relation of the discharge required, to the discharge of the sewer running full.

Suppose the diameter of the sewer to be 12 inches.
Do. the inclination of the sewer to be 1 in 200.
Do. the depth of flow to be 5 inches.

Solution $\frac{5}{12} = 0{\cdot}416$; trace the horizontal line to its intersection with the curve of discharge and then below that point vertically, on the base line is read 0·36. The discharge at 5″ depth is 36 per cent. of that when the sewer is running full or $\frac{167{\cdot}2 \times 36}{100} = 60{\cdot}192$ cubic feet per minute.

The following tables give the discharges, in cubic feet per minute, of circular sewers running full at various rates of inclination:—

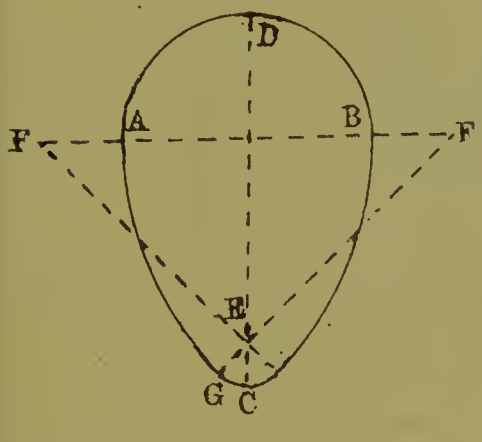
Discharges in Cubic Feet per Minute from Circular Sewers from 6 inches to 60 inches Diameter. Sewers Running Full.

Inclination.	Size.														Inclination.
	6″	9″	12″	15″	18″	21″	24″	27″	30″	36″	42″	48″	54″	60″	
1 in 20	94·42	257·1	521·5	900·6	1,403	2,039	2,815								1 in 20
1 in 25	84·80	232·0	471·2	814·7	1,272	1,854	2,564								1 in 25
1 in 30	77·54	212·5	432·8	749·7	1,173	1,710	2,372								1 in 30
1 in 35	71·85	197·0	402·9	698·2	1,094	1,597	2,215								1 in 35
1 in 40	67·14	184·7	377·8	656·4	1,028	1,503	2,086								1 in 40
1 in 45	63·21	174·5	356·6	620·9	973·6	1,424	1,980								1 in 45
1 in 50	60·17	165·7	339·1	590·2	927·7	1,356	1,885								1 in 50
1 in 60	54·68	151·6	310·1	539·9	849·9	1,243	1,731								1 in 60
1 in 70	50·37	140·1	287·3	500·6	788·1	1,157	1,612								1 in 70
1 in 80	46·84	130·8	268·5	468·7	738·6	1,085	1,511								1 in 80
1 in 90	44·10	123·3	252·8	441·7	696·2	1,025	1,427								1 in 90
1 in 100	41·75	116·7	240·2	419·6	660·9	971·6	1,357	1,817	2,361	3,711	5,426	7,540	10,067	13,038	1 in 100
1 in 110	39·59	110·9	228·4	400·0	630·8	928·3	1,298	1,734	2,253	3,542	5,186	7,213	9,638	12,488	1 in 110
1 in 120	37·83	106·1	218·2	382·8	604·3	887·4	1,241	1,662	2,160	3,400	4,974	6,924	9,256	11,997	1 in 120
1 in 130	36·46	101·7	209·6	366·9	579·6	853·8	1,191	1,594	2,077	3,273	4,791	6,673	8,924	11,565	1 in 130
1 in 140	34·89	97·68	201·7	353·4	558·4	822·5	1,147	1,539	2,003	3,153	4,628	6,446	8,620	11,172	1 in 140
1 in 150	33·71	94·15	194·7	341·1	540·7	793·6	1,109	1,487	1,939	3,054	4,474	6,233	8,350	10,819	1 in 150
1 in 160	32·54	91·05	188·4	330·1	523·0	769·6	1,075	1,439	1,875	2,955	4,339	6,044	8,095	10,505	1 in 160
1 in 170	31·36	87·96	182·1	320·2	507·1	745·5	1,043	1,399	1,821	2,870	4,214	5,868	7,857	10,210	1 in 170
1 in 180	30·38	85·31	176·6	310·4	491·2	723·9	1,012	1,360	1,772	2,792	4,099	5,705	7,650	9,935	1 in 180
1 in 190	29·60	83·10	171·9	301·8	477·1	704·6	983·4	1,324	1,723	2,715	3,993	5,554	7,443	9,680	1 in 190
1 in 200	28·81	80·89	167·2	293·3	464·7	685·4	958·3	1,288	1,679	2,651	3,887	5,416	7,268	9,444	1 in 200
1 in 250	25·68	72·05	148·4	261·4	413·5	610·9	854·6	1,153	1,497	2,368	3,483	4,863	6,537	8,503	1 in 250
1 in 300	23·13	64·97	135·0	236·8	376·4	555·5	779·2	1,050	1,365	2,156	3,175	4,436	5,964	7,756	1 in 300
1 in 350		59·67	124·0	218·4	346·3	512·3	716·4	966·2	1,257	1,993	2,944	4,109	5,519	7,186	1 in 350
1 in 400		55·69	115·4	203·7	323·4	478 6	669·2	898·6	1,173	1,859	2,742	3,845	5,169	6,715	1 in 400
1 in 450		52·16	108·3	191·4	303·9	449·7	628·4	846·9	1,105	1,746	2,578	3,632	4,883	6,342	1 in 450
1 in 500			102·05	180·4	286·3	425·7	593·8	803·1	1,046	1,654	2,444	3,431	4,612	6,008	1 in 500
1 in 550			97·34	171·8	272·1	404·0	565·6	763·4	996·5	1,576	2,328	3,267	4,390	5,714	1 in 550

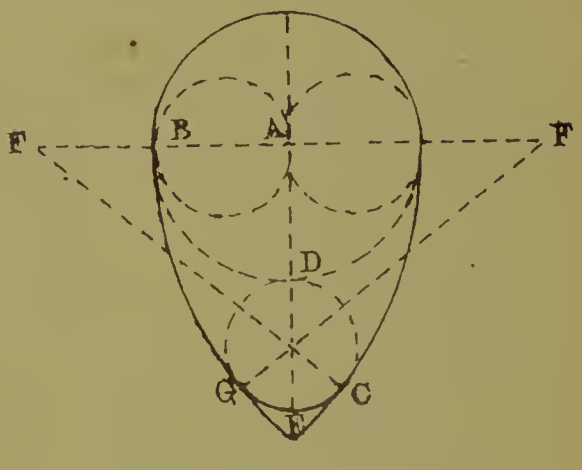
Discharges in Cubic Feet per Minute from Circular Sewers from 6 inches to 60 inches Diameter-Sewers running full—cont.

Inclination	Size. 6″	9″	12″	15″	18″	21″	24″	27″	30″	36″	42″	48″	54″	60″	Inclination.
1 in 600			92·63	164·4	259·7	384·8	540·4	727·6	952·3	1,506	2,222	3,116	4,183	5,458	1 in 600
1 in 650				157·1	249·1	368·0	518·4	695·8	913·1	1,442	2,136	2,991	4,008	5,243	1 in 650
1 in 700				150·9	238·5	353·5	496·4	668·0	878·7	1,385	2,049	2,878	3,865	5,046	1 in 700
1 in 750				144·8	229 7	341·5	477·6	644·1	844·3	1,336	1,972	2,777	3,737	4,869	1 in 750
1 in 800					222·6	329·5	461·9	624·2	814·9	1,294	1,915	2,677	3,594	4,693	1 in 800
1 in 850					215·6	319·9	446·2	604·3	790·3	1,251	1,857	2,589	3,483	4,536	1 in 850
1 in 900					208·5	310·2	433·6	584·5	765·8	1,216	1,799	2,513	3,388	4,418	1 in 900
1 in 950						300·6	421·0	568·5	741·3	1,181	1,741	2,450	3,292	4,300	1 in 950
1 in 1000						291·0	408·5	552·6	721·6	1,145	1,693	2,388	3,213	4,182	1 in 1000
1 in 1100							389·6	524·8	687·3	1,089	1,616	2,274	3,054	3,986	1 in 1100
1 in 1200							370·8	501·0	652·9	1,039	1,539	2,161	2,910	3,790	1 in 1200
1 in 1300								477·1	623·4	996·7	1,472	2,073	2,783	3,632	1 in 1300
1 in 1400									598·9	954·3	1,414	1,985	2,672	3,495	1 in 1400
1 in 1500									579·3	919·0	1,366	1,910	2,576	3,377	1 in 1500
1 in 1600										890·7	1,318	1,847	2,497	3,259	1 in 1600
1 in 1700										862·4	1,280	1,784	2,417	3,161	1 in 1700
1 in 1800										834·1	1,241	1,734	2,338	3,063	1 in 1800
1 in 1900											1,203	1,684	2,274	2,965	1 in 1900
1 in 2000											1,164	1,634	2,211	2,886	1 in 2000
1 in 2100												1,596	2,147	2,808	1 in 2100
1 in 2200												1,558	2,099	2,749	1 in 2200
1 in 2300												1,520	2,052	2,670	1 in 2300
1 in 2400												1,483	2,004	2,611	1 in 2400
1 in 2500													1,956	2,553	1 in 2500
1 in 2600													1,908	2,513	1 in 2600
1 in 2700													1,877	2,454	1 in 2700
1 in 2800														2,415	1 in 2800
1 in 2900														2,356	1 in 2900
1 in 3000														2,317	1 in 3000

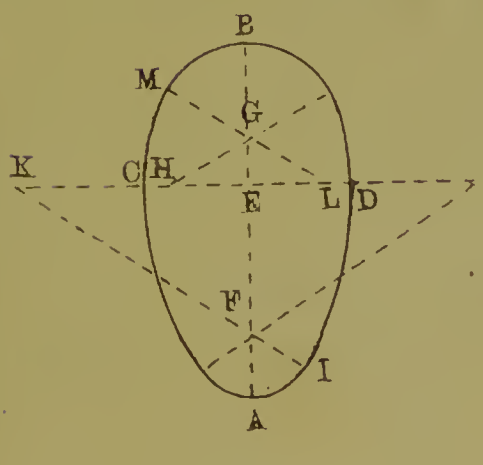
Oval sewers.—The tables given above relate only to circular sewers; where the sewers have to carry off volumes, which vary considerably in quantity, a sewer of different section is adopted, so as to maintain as great a depth of flow as possible, even when the volume is small; these sewers are of oval shape, and may be of any of the following sections, but that marked as No. 1 is the form now generally adopted :—



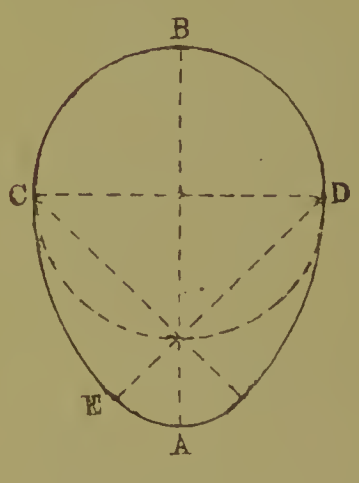
No. 1



No. 2



No. 3



No. 4

Proportions of oval sewers.—The following are the proportions of these oval sewers :—

No. 1. The vertical height C D is equal to one and one-half times the transverse diameter A B; the radius of the

invert E G equals one-eighth part of the transverse diameter; the radius of the sides equals one and one-third times the transverse diameter. This section is sometimes called the new oval form of sewer as opposed to No. 2, the old form.

No. 2. The vertical height equals one and-one-half times the transverse diameter; the radius of the invert equals one-fourth the transverse diameter; the radius of the sides equals one and one-half times the transverse diameter.

No. 3. The vertical height equals one and two-third times the transverse diameter; the radius of the invert equals one-fourth of the transverse diameter. A E = C D, and C H = $\frac{1}{6}$ C D and I K is parallel to L M. This form is used only when extra height is desirable.

No. 4. The construction is easily understood from the diagram; this form is of easy construction, but does not carry off small volumes so well as Nos. 1, 2 or 3 forms.

Hydraulic mean depths of oval sewers.—As shown for circular pipes or sewers flowing full or half full, the HMD is equal to one-fourth part of the diameter, but in oval sewers no such proportion obtains, and at each depth it has to be calculated.

For the new form No. 1 the hydraulic mean depth may be found thus:—

Sewer full,	HMD = 0·2844	(of transverse diameter).
Do. two-thirds full,	HMD = 0·3074	(do.).
Do. one-third full,	HMD = 0·1920	(do.).

For the old form No. 2 the H.M.D$_s$ will be:—

Sewer full,	HMD = 0·2897	(of transverse diameter).
Do. two-thirds full,	HMD = 0·3157	(do.).
Do. one-third full,	HMD = 0·2066	(do.).

The following tables will be found useful in determining discharges from oval sewers of the two forms:—

Table showing the Discharges in Cubic Feet per Minute from Oval Sewers, new form No. 1, running full.

Inclination.	Size. 1′ 0″ × 1′ 6″	1′ 4″ × 2′ 0″	1′ 6″ × 2′ 3″	2′ 0″ × 3′ 0″	2′ 6″ × 3′ 9″	3′ 0″ × 4′ 6″	3′ 6″ × 5′ 3″	4′ 0″ × 6′ 0″	Inclination.
1 in 100	363	747	1,001	1,877					1 in 100
1 in 110	346	712	956	1,782					1 in 110
1 in 120	331	682	916	1,705					1 in 120
1 in 130	318	656	881	1,640					1 in 130
1 in 140	306	630	848	1,583					1 in 140
1 in 150	295	608	818	1,531	2,927				1 in 150
1 in 160	285	589	793	1,482	2,836				1 in 160
1 in 170	277	571	768	1,437	2,753				1 in 170
1 in 180	269	555	745	1,397	2,676	4,214			1 in 180
1 in 190	261	539	725	1,360	2,606	4,104			1 in 190
1 in 200	254	525	707	1,324	2,544	4,004	5,873	8,206	1 in 200
1 in 250	226	468	630	1,181	2,272	3,592	5,272	7,350	1 in 250
1 in 300	205	424	572	1,076	2,070	3,271	4,821	6,726	1 in 300
1 in 350	188	392	527	991	1,916	3,030	4,453	6,226	1 in 350
1 in 400	176	365	492	926	1,784	2,830	4,166	5,816	1 in 400
1 in 450	165	343	462	869	1,679	2,659	3,920	5,477	1 in 450
1 in 500	156	323	437	824	1,589	2,519	3,715	5,191	1 in 500
1 in 550	148	307	414	784	1,512	2,388	3,537	4,942	1 in 550
1 in 600	141	293	396	747	1,443	2,288	3,374	4,728	1 in 600
1 in 650	135	281	379	715	1,387	2,198	3,237	4,531	1 in 650
1 in 700		270	364	686	1,331	2,107	3,114	4,353	1 in 700
1 in 750		260	351	662	1,282	2,037	3,005	4,210	1 in 750
1 in 800		252	339	641	1,240	1,967	2,909	4,068	1 in 800
1 in 850		244	329	621	1,199	1,907	2,814	3,943	1 in 850
1 in 900		236	319	601	1,164	1,846	2,732	3,818	1 in 900
1 in 950			309	585	1,129	1,796	2,650	3,711	1 in 950
1 in 1000			301	568	1,101	1,746	2,581	3,622	1 in 1000
1 in 1100				540	1,045	1,656	2,459	3,443	1 in 1100
1 in 1200				516	997	1,585	2,336	3,283	1 in 1200
1 in 1300				491	955	1,515	2,240	3,140	1 in 1300
1 in 1400					920	1,455	2,158	3,015	1 in 1400
1 in 1500					885	1,405	2,076	2,908	1 in 1500
1 in 1600					850	1,355	2,008	2,819	1 in 1600
1 in 1700						1,315	1,940	2,730	1 in 1700
1 in 1800						1,274	1,885	2,640	1 in 1800
1 in 1900						1,234	1,830	2,569	1 in 1900
1 in 2000						1,204	1,776	2,498	1 in 2000
1 in 2100							1,735	2,426	1 in 2100
1 in 2200							1,694	2,373	1 in 2200
1 in 2300							1,653	2,319	1 in 2300
1 in 2400								2,266	1 in 2400
1 in 2500								2,212	1 in 2500
1 in 2600								2,159	1 in 2600

Table showing Area and Hydraulic mean depth of Oval Sewers (No. 1), new form.

Size of sewer.	Sectional area when running full.	Sectional area when flowing $\frac{3}{3}$rds vertical height.	Sectional area when flowing $\frac{1}{3}$rd vertical height.	Hydraulic mean depth flowing full.	Hydraulic mean depth flowing $\frac{2}{3}$rds vertical height.	Hydraulic mean depth flowing $\frac{1}{3}$rd vertical height.
	FEET.	FEET.	FEET.	FEET.	FEET.	FEET.
1′ 0″ × 1′ 6″	1·1150	·7223	·2543	·2844	·3074	·1920
1′ 2″ × 1′ 9″	1·5176	·9831	·3461	·3318	·3586	·2240
1′ 4″ × 2′ 0″	1·9822	1·2841	·4521	·3792	·4099	·2560
1′ 6″ × 2′ 3″	2·5087	1·6252	·5722	·4266	·4611	·2880
1′ 8″ × 2′ 6″	3·0972	2·0064	·7064	·4740	·5123	·3200
1′ 10″ × 2′ 9″	3·7476	2·4277	·8547	·5214	·5636	·3520
2′ 0″ × 3′ 0″	* 4·4600	2·8892	1·0172	·5688	·6148	·3840
2′ 2″ × 3′ 3″	5·2343	3·3908	1·1938	·6162	·6660	·4160
2′ 4″ × 3′ 6″	6·0705	3·9325	1·3845	·6636	·7173	·4480
2′ 6″ × 3′ 9″	6·9687	4·5144	1·5894	·7110	·7685	·4800
2′ 8″ × 4′ 0″	7·9288	5·1364	1·8084	·7584	·8197	·5120
2′ 10″ × 4′ 3″	8·9509	5·7985	2·0415	·8058	·8710	·5440
3′ 0″ × 4′ 6″	10·0349	6·5007	2·2887	·8532	·9222	·5760
3′ 2″ × 4′ 9″	11·1809	7·2431	2·5501	·9006	·9734	·6080
3′ 4″ × 5′ 0″	12·3888	8·0256	2·8256	·9480	1·0247	·6400
3′ 6″ × 5′ 3″	13·6586	8·8482	3·1152	·9954	1·0759	·6720
3′ 8″ × 5′ 6″	14·9904	9·7110	3·4190	1·0428	1·1271	·7040
3′ 10″ × 5′ 9″	16·3842	10·6139	3·7369	1·0902	1·1784	·7360
4′ 0″ × 6′ 0″	17·8399	11·5569	4·0689	1·1376	1·2296	·7680

* If this number (4·46) is multiplied by the square of the radius in feet of the arched covering of an oval sewer of this particular sectional proportion, it will give the sectional area of the sewer.

Table showing the Discharges in Cubic Feet per Minute from old form of Sewer (No. 2) running full.

Inclination.	Size. 1′ 0″ × 1′ 6″	1′ 4″ × 2′ 0″	1′ 6″ × 2′ 3″	2′ 0″ × 3′ 0″	2′ 6″ × 3′ 9″	3′ 0″ × 4′ 6″	3′ 6″ × 5′ 3″	4′ 0″ × 6′ 0″	Inclination.
1 in 100	378	778	1,044	2,127					1 in 100
1 in 110	361	741	995	2,030					1 in 110
1 in 120	345	708	951	1,948					1 in 120
1 in 130	331	682	915	1,874					1 in 130
1 in 140	318	655	880	1,805					1 in 140
1 in 150	307	633	850	1,746					1 in 150
1 in 160	296	613	824	1,691					1 in 160
1 in 170	287	594	798	1,633					1 in 170
1 in 180	279	576	775	1,588					1 in 180
1 in 190	271	562	755	1,553					1 in 190
1 in 200	264	546	734	1,511	2,642	4,165	6,120	8,508	1 in 200
1 in 250	235	486	654	1,351	2,362	3,731	5,487	7,644	1 in 250
1 in 300	213	442	595	1,231	2,153	3,411	5,009	6,983	1 in 300
1 in 350	196	406	548	1,135	1,988	3,142	4,629	6,468	1 in 350
1 in 400	183	380	512	1,057	1,859	2,935	4,333	6,046	1 in 400
1 in 450	171	355	481	997	1,751	2,770	4,080	5,715	1 in 450
1 in 500	162	337	455	942	1,651	2,615	3,855	5,403	1 in 500
1 in 550	154	321	432	896	1,572	2,481	3,672	5,145	1 in 550
1 in 600	147	304	411	854	1,500	2,377	3,503	4,906	1 in 600
1 in 650	141	292	393	816	1,436	2,284	3,363	4,723	1 in 650
1 in 700	136	280	377	786	1,385	2,191	3,236	4,539	1 in 700
1 in 750		269	364	758	1,335	2,119	3,123	4,373	1 in 750
1 in 800		261	351	730	1,292	2,047	3,025	4,226	1 in 800
1 in 850		253	341	707	1,249	1,985	2,926	4,098	1 in 850
1 in 900		245	331	689	1,206	1,923	2,828	3,969	1 in 900
1 in 950			320	666	1,170	1,861	2,743	3,859	1 in 950
1 in 1000			313	648	1,141	1,809	2,673	3,767	1 in 1000
1 in 1100				615	1,091	1,726	2,547	3,583	1 in 1100
1 in 1200				588	1,041	1,643	2,434	3,418	1 in 1200
1 in 1300				560	998	1,571	2,335	3,271	1 in 1300
1 in 1400					955	1,509	2,237	3,142	1 in 1400
1 in 1500					919	1,457	2,153	3,032	1 in 1500
1 in 1600					883	1,406	2,082	2,922	1 in 1600
1 in 1700					854	1,364	2,026	2,830	1 in 1700
1 in 1800						1,323	1,956	2,738	1 in 1800
1 in 1900						1,282	1,899	2,665	1 in 1900
1 in 2000						1,251	1,843	2,591	1 in 2000
1 in 2100							1,801	2,518	1 in 2100
1 in 2200							1,759	2,462	1 in 2200
1 in 2300							1,716	2,407	1 in 2300
1 in 2400							1,674	2,352	1 in 2400
1 in 2500								2,297	1 in 2500
1 in 2600								2,242	1 in 2600

Table showing Area and Hydraulic mean depth of Oval Sewers (No. 2), old form.

Size of sewer.	Sectional area when running full.	Sectional area when flowing ¾rds vertical height.	Sectional area when flowing ½rd vertical height.	Hydraulic mean depth flowing full.	Hydraulic mean depth flowing ¾rds vertical height.	Hydraulic mean depth flowing ½rd vertical height.
	FEET.	FEET.	FEET.	FEET.	FEET.	FEET.
1′ 0″ × 1′ 6″ ...	1·1485	0·7558	0·2840	0·2897	0·3157	0·2066
1′ 2″ × 1′ 9″ ...	1·5632	1·0287	0·3865	0·3380	0·3683	0·2410
1′ 4″ × 2′ 0″ ...	2·0418	1·3436	0·5049	0·3863	0·4209	0·2755
1′ 6″ × 2′ 3″ ...	2·5841	1·7005	0·6390	0·4345	0·4735	0·3099
1′ 8″ × 2′ 6″ ...	3·1903	2·0994	0·7889	0·4828	0·5262	0·3443
1′ 10″ × 2′ 9″ ...	3·8602	2·5402	0·9545	0·5311	0·5788	0·3786
2′ 0″ × 3′ 0″ ...	*4·5940	3·0232	1·1360	0·5794	0·6314	0·4132
2′ 2″ × 3′ 3″ ...	5·3916	3·5480	1·3332	0·6277	0·6840	0·4476
2′ 4″ × 3′ 6″ ...	6·2529	4·1149	1·5462	0·6760	0·7366	0·4820
2′ 6″ × 3′ 9″ ...	7·1781	4·7237	1·7750	0·7242	0·7892	0·5165
2′ 8″ × 4′ 0″ ...	8·1671	5·3746	2·0195	0·7725	0·8418	0·5409
2′ 10″ × 4′ 3″ ...	9·2199	6·0674	2·2799	0·8208	0·8944	0·5852
3′ 0″ × 4′ 6″ ...	10·3365	6·8022	2·5560	0·8691	0·9471	0·6198
3′ 2″ × 4′ 9″ ...	11·5169	7·5790	2·8479	0·9174	0·9997	0·6542
3′ 4″ × 5′ 0″ ...	12·7611	8·3978	3·1556	0·9657	1·0523	0·6887
3′ 6″ × 5′ 3″ ...	14·0691	9·2585	3·4790	1·0139	1·1049	0·7231
3′ 8″ × 5′ 6″ ...	15·4099	10·1613	3·8182	1·0622	1·1576	0·7575
3′ 10″ × 5′ 9″ ...	16·8766	11·1061	4·1732	1·1105	1·2102	0·7920
4′ 0″ × 6′ 0″ ...	18·3760	12·0928	4·5440	1·1588	1·2628	0·8264

* If this number (4·5940) is multiplied by the square of the radius of the top arch of an oval sewer of similar proportions, it will give the area of the sewer.

In properly laid sewers, the horizontal curves used are not such as require any increased head to overcome friction due to change in angular direction, but increased roughness of work or of pipes at such places sometimes requires an allowance; the following formula is said to give good results as to pipe sewers:—

$$H = \frac{v\ 2l}{4000\ d}\left\{1 + \frac{10\ d}{r}\right\}$$

in which v = velocity in feet per second,
l = length of curve in feet,
d = diameter of pipe,
r = radius of axis of curve in feet,
H = loss of head (*i.e.*, the *total* loss of head in the curved portion.

It is usual to give at all bends, a little extra fall to compensate for the increased friction.

Small sewers should be circular.—All small sewers ought to be circular, and for ordinary purposes it is found in practice that sewers up to, and including, 18 inches in diameter

should be of stoneware, fire-clay or cement * pipes. Oval pipes have been tried, but they are difficult to manufacture truly to shape, and as difficult to lay truly with tight joints. In sewers above 18 inches in diameter, if there is sufficient sewage to keep the sewers constantly running half full, these should also be circular, as that is the cheapest and strongest form of sewer; where that is not the case, it is well to adopt the oval form. It is inadvisable to construct sewers of less than 9 inches in diameter; small sewers are very liable to frequent stoppages. House drains,† with well-formed traps, may be of smaller dimensions.

CONSTRUCTION OF SEWERS.

Materials used in construction.—For the construction of sewers the materials used are bricks, tiles, stone, stoneware, asphalte, concrete, cement, lime, iron and timber. It is necessary to use the best materials available, as the sewers are subject to eroding action from the materials transported through them, and also, to chemical action from the constituents of the sewage. The smaller sewers and house-drains are usually constructed of glazed stoneware or fire-clay pipes. Fire-clay pipes are not so strong nor so durable, thickness for thickness, as stoneware pipes, but they are less brittle and less liable to fracture.

* Cement pipes for sewers up to 18 inches diameter are now made in Madras. They cost about the same rate per foot as stoneware pipes.

Table showing results of tests, of cement pipes made at the Madras Cement Works, 1895.

Number of test.	Number of pipes tested.	Pressure applied in lb.	Head in feet.	Pipes burst or cracked.	Result of test.
I ...	4	12	28	Cracked.	Last pipe from socket end cracked at the end. Fracture nearly even and almost as if it had been cut.
II ...	3	14	32	Do.	Last pipe from socket end cracked at the end. Fracture was zigzag.
III ...	2	21	49	Do.	Disc blown out.
IV ...	2	18	42	Do.	Fracture same as test No. I.
V ...	2	31	71	Do.	Joint gave way bringing a piece of socket of the pipe.
VI ...	1	25	58	Do.	Fracture zagged.
VII ...	1	53	122½	Broken.	
VIII ...	1	25	58	Do.	Fracture zigzag.
IX ...	1	55	127	Cracked.	Zigzag. The best result.
Total ...	...	254	587	...	
Average...	...	28	65	...	

NOTE.—When more pipes than one were tested together they were jointed with Portland cement. The end pipes were closed by iron discs and jointed on to the pipes with either lead or cement.

† Sewers are channels which receive the drainage from many houses. Drains are those connected with one house only.

Pipes are made usually of the dimensions given in the following table:—

Stoneware, Messrs. Henry Doulton and Co., Lambeth.					Fire clay, Messrs. Ingham and Son, Wortley.					Stoneware, Messrs. Burn and Co., Calcutta.				
Internal diameter.	Thickness.	Length in work.	Depth of socket.	Weight of foot.	Internal diameter.	Thickness.	Length in work.	Depth of socket.	Weight of foot.	Internal diameter.	Thickness.	Length in work.	Depth of socket.	Weight of foot.
INCHES.	INCHES.	FEET.	INCHES.	LB.	INS.	INS.	FT. INS.	INS.	LB.	INS.	INS.	FEET.	INS.	LB.
3	$\frac{1}{2}$	2	$1\frac{1}{2}$	6	3	$\frac{5}{8}$	2 0	$1\frac{1}{2}$	6·4	3	$\frac{7}{16}$	2	$1\frac{1}{2}$	$5\frac{1}{4}$
4	$\frac{5}{8}$	2	$1\frac{1}{2}$	9	4	$\frac{11}{16}$	2 0	$1\frac{1}{2}$	8·12	4	$\frac{5}{8}$	2	$1\frac{1}{2}$	$9\frac{3}{4}$
6	$\frac{11}{16}$	2	$1\frac{3}{4}$	$14\frac{1}{2}$	6	$\frac{3}{4}$	2 0	$1\frac{1}{2}$	13·8	6	$\frac{3}{4}$	2	$1\frac{3}{4}$	$16\frac{1}{4}$
9	$\frac{13}{16}$	2	2	28	9	$\frac{3}{4}$	2 0	$1\frac{5}{8}$	21·4	9	$\frac{7}{8}$	2	$1\frac{3}{4}$	$31\frac{1}{4}$
10	$\frac{7}{8}$	2	2	29	10	$\frac{13}{16}$	2 0	$1\frac{5}{8}$	24·4	...	...	...	...	...
12	1	2	2	46	12	$1\frac{1}{8}$	2 6	2	41·10	12	1	2	$1\frac{3}{4}$	44
15	$1\frac{1}{4}$	2 to 3	$2\frac{1}{4}$	72	15	$1\frac{1}{4}$	2 6	2	61·2	15	1	2	2	$60\frac{1}{4}$
18	$1\frac{3}{8}$	2 to 3	$2\frac{1}{4}$	91	18	$1\frac{3}{8}$	2 6	$2\frac{1}{4}$	83·2	18	$1\frac{1}{8}$	2	$2\frac{1}{8}$	$91\frac{1}{4}$

Porosity of pipes.—All earthenware and fire-clay pipes absorb more or less water. The following table shows the absorption of water by sewer pipes from various makers :—

Name of maker.	Size of pipe as measured.	Length of pipe as measured, exclusive of socket.	Thickness of pipe.	Weight in lb. when dry.	Weight in lb. after 24 hours' immersion in water.	Amount of water absorbed.	Percentage of water absorbed by dry pipe.
	INCHES.	FT. IN.	INCHES.	LB.	LB.	LB.	
Doulton and Co., London pipe ...	6	1 11	·75	31·00	31·25	·25	·806
S. Fisher	6	2 0	·63	28·00	28·75	·75	2·68
Doulton and Co., London pipe ...	9	2 0	·87	57·75	58·75	1·00	1·73
Do. Staffordshire pipe.	9	1 11	·87	51·75	53·00	1·25	2·41
Do. do. ...	12	2 0	1·05	96·0	97·5	1·50	1·56
S. Fisher	12	1 11	1·00	84·0	88·0	4·00	4·76
Doulton and Co., London pipe ...	15	1 11	1·06	116·5	117·0	·50	·429
Do. Staffordshire pipe ...	15	2 6	1·26	132·0	139·0	7·00	5·30
Doulton and Co.	18	2 4	1·43	221·0	226·00	5·00	2·26
Do.	18	2 5	1·38	210·0	217·0	7·00	3·33

Test of porosity.—To test the porosity of pipes; after tying a bladder or other waterproof substance on one end, set the pipe upon that end and fill it with water. The sweating of the pipe will show if it is porous, and if the fall of water in the pipe be measured, the loss will show the amount absorbed.

Pipes as sewers subjected to crushing.—Pipes, when laid as a sewer, are subjected to severe crushing strain, but the thickness of pipes given is usually sufficient for all practical purposes.

Selection of pipes.—Great care is necessary in the selection of pipes; they must be true in section, perfectly straight and well formed at the joints. Salt-glazed pipes are more durable than lead-glazed pipes. The pipes of Messrs. Burn and Co., Calcutta, are salt-glazed, and are of excellent material, and large quantities of them have been used in drainage works throughout India.

The following table shows the result of some experiments made by Public Works and other officers with these and other pipes at Jubbulpore in February 1894:—

ABSTRACT OF EXPERIMENTS WITH GLAZED STONEWARE PIPES.

Internal pressure by means of hydraulic power. External pressure by means of Lever and Weights.

Serial number of experiments.	Maker's name.	Where made.	Internal diameter of pipe.	Bursting internal pressure in lb. per square inch.	Breaking external pressure in lb.
27	Burn & Co. ...	Raneegunge ...	4	200 *	...
28	Do. ...	Jubbulpore § ...	4	200 *	...
1	Do. ...	Do. ...	6	85 †	...
2	Do. ...	Do. ...	6	200 †	...
3	Do. ...	Do. ...	6	‡ 200 *	...
24	Do. ...	Do. ...	6	‡ 200 *	...
23	Do. ...	Raneegunge ...	6	‡ 200 *	...
5	Doulton's ...	England ...	9	122	...
15	Do. ...	Do. ...	9	102	...

* All pipes marked thus went up to the maximum indicated by the pressure gauge without bursting.

† These pipes had no socket. ‡ Ordinary socket pipes.

§ Pipes marked thus were prepared at Raneegunge from clays obtained from Jubbulpore.

Internal pressure by means of hydraulic power. External pressure by means of Lever and Weights—continued.

Serial number of experiments.	Maker's name.	Where made.	Internal diameter of pipe.	Bursting internal pressure in lb. per square inch.	Breaking external pressure in lb.
26	Doulton's ...	England ...	9	92	...
6	Burn & Co. ...	Jubbulpore ...	9	200 *	...
14	Do. ...	Do. ...	9	136	...
22	Do. ..	Do. ...	9	140	...
25	Do. ...	Raneegunge ...	9	200 *	...
4	Doulton's ...	England ...	12	aban-doned. ‖	...
12	Do. ...	Do. ...	12	90	...
13	Do. ...	Do. ...	12	80	...
10	Burn & Co. ...	Jubbulpore ...	12	110 ¶	...
11	Do. ...	Do. ...	12	‡ 160	...
20	Do. ...	Do. † ...	§12	‡ 134	...
21	Do. ...	Do. † ...	§12	‡ 132	...
19	Do. ...	Raneegunge ...	12	136	...
29	Do. ...	Jubbulpore † ...	15	82	...
30	Do. ...	Raneegunge ...	15	105	...
18	Do. ...	Jubbulpore ..	6	...	5,809
7	Do. ...	Do. ...	9	...	** 3,947
9	Do. ...	Raneegunge ..	9	...	3,212
8	Doulton's ...	England ...	9	...	2,673
16	Do. ...	Do. ...	12	...	3,646
33	Do. ...	Do. ...	12	...	3,215
17	Burn & Co. ...	Jubbulpore ...	12	..	4,794½
34	Do. ...	Raneegunge ...	12	...	3,646
31	Do. ...	Do. ...	15	...	4,794
32	Do. ...	Jubbulpore † ...	15	...	5,039

Cement pipes are made of the same form as stoneware pipes; they have been extensively used in Germany and show an extraordinary amount of endurance, and as cement continues to harden for years, they are thus of peculiar advantage, especially in damp situations. They have another

* All pipes marked thus went up to the maximum indicated by the pressure gauge without bursting.

† These pipes had no socket.

‡ Ordinary socket pipes.

§ Pipes marked thus were prepared at Raneegunge from clays obtained from Jubbulpore.

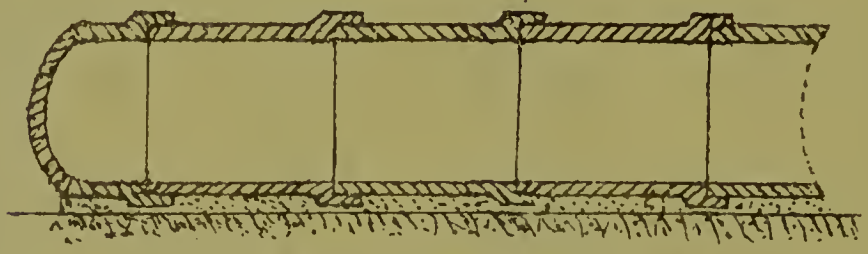
‖ Ordinary socket pipe; failed to make a good joint.

¶ This ordinary socket pipe was tightened up under pressure and its chance spoilt thereby.

** This pipe carried the weight without breaking.

advantage and that is they can be manufactured on the site of the works ; much expense may be saved by carrying the cement to the works instead of the finished pipes. Where stoneware pipes have to be imported from England or carried long distances by rail, the question of using cement pipes in their place is an important economical consideration. Cement pipes are manufactured at the Madras Cement Works and some 6″ pipes have stood a head of 35 feet of water. Such pipes may also be used for water-supply when the greatest statical head does not exceed a safe proportion of their bursting pressure.

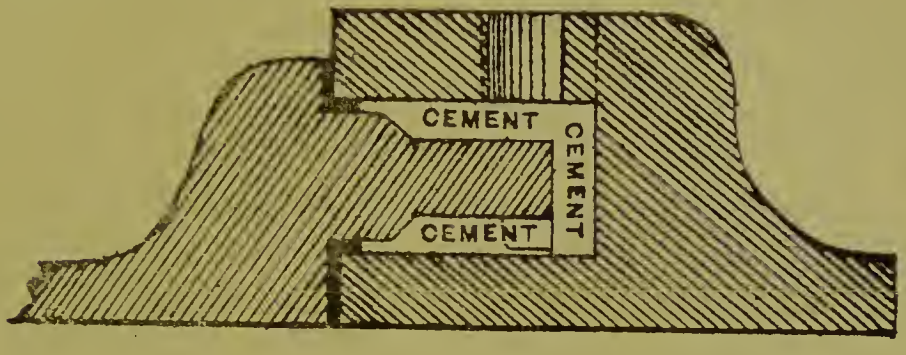
Method of laying pipe sewers.—The pipes generally used are ordinary socketed pipes, and when laid, the spigot of one pipe is inserted into the socket of another ; the spigot end of the pipe should always be downhill. When laying pipes, great attention must be given to ensure that they have a uniform bearing, and instead of cutting a hollow in the trench, or concrete, under the socket portion of the pipe, it is better to let the sockets rest on the concrete bed and then to fill in under the remaining length of the pipe, thus—



Trench Floor or Surface of Concrete

Jointing pipes.—Pipes should be jointed with Portland cement used neat, or with a proportion of sand not exceeding 3 of sand to 1 of cement. Every pipe should be jointed as laid, and a second pipe should not be laid until it has been ascertained that no cement of the joint previously laid has passed into the inside of the pipe. In some cases tarred yarn is wound round the pipe socket before placing it in position, and the remainder of the joint is then filled in with cement as usual. This plan prevents cement getting into the pipes. In laying pipes and in brick sewers, it is advisable to put in junctions for branch sewers and house drains at the time the sewer is laid ; the after-insertion of a junction in a pipe sewer is difficult, and at least three pipes must be taken out before it can be effected.

Patent joints.—When pipes have to be laid in very wet trenches, it is advisable to adopt a special form of joint; Standford's or Syke's patent joints are forms used; the 'Archer joint' illustrated below has found much favour. These joints are filled by pouring in, through a hole in the top of the socket, some liquid material such as liquid cement or asphalte, &c., which hardens in the joint.

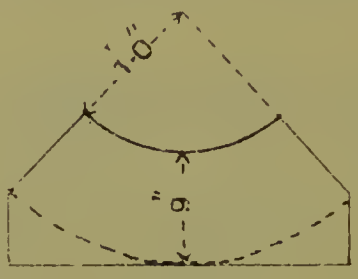


Concrete necessary to keep out tree roots.—Where a pipe sewer is laid near trees, the pipes ought to be imbedded in concrete, and the joints ought to be formed with asphalte, which kills the rootlets. Roots of trees often extend considerable distances in search of water, and will readily enter the joints of pipes; not only ought trees to be avoided, but also any ground creepers; the author has seen an 18-inch sewer completely filled up by the roots of the rabbit-wort creeper; this was, however, a brick sewer, which is more pervious to roots than a pipe sewer.

Selection of bricks for sewers.—For brick sewers the bricks require to be carefully selected, and the usual tests for absorption ought to be applied to all bricks to be used. They should be fairly well shaped and show considerable resistance to crushing strain, which is the only strain against which they have to contend. In the smaller sewers, specially shaped or gauged bricks will be required, or the joints on the back will be very open and pervious to water. Soft bricks should, on no account, be used in sewers, but a slightly rough face is not a material drawback; the sides of the bricks adjacent to the sewer ought, however, to present a fairly smooth surface. Pressed or glazed bricks form an excellent facing for the inside of sewers; where economy prevents their use, the inside of the sewers must be plastered.

Construction of sewers below water level.—In building sewers below water level, it is advisable to make blocks for the lower or invert portion, and this may be done

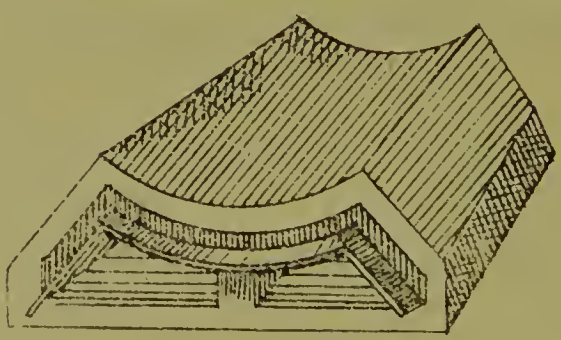
either by cementing bricks together to the required form or by making blocks of concrete in moulds especially made for the purpose. This latter plan was adopted in the Madras sewers, where blocks, 2 feet long, of the following section were used :—



They were composed of by measure—

Portland cement	1 part.
Gravel	6 parts.
Sand	3 do.

They were allowed to set not less than 14 days before use. Invert blocks made of stoneware, solid or hollow, are largely manufactured. Such blocks greatly facilitate the construction of sewers, and from their durability and smoothness of surface are well adapted for the purpose. The following is a sketch of a hollow invert block :—



These blocks are also advantageous in so far that they afford a ready means of draining off the subsoil water during construction. The ends of the channels thus formed must, however, be blocked when no longer required; the flow through them is apt to carry off soil from below the sewers and undermine them.

Precautions necessary in building sewers.—In building sewers, templates made true to the section of the sewer should invariably be used. Care must be taken to ensure the use of an amount of material sufficient to fill up every crevice in the work, in order to render the sewers as water-tight as possible. When a brick sewer, laid in bad ground or in ground saturated with water, is made up of several rings, a layer of cement ought to pass between each ring, the joints ought not to exceed one-fourth of an inch in thickness, and the cement should be well pressed into the joints with the trowel. The arches are executed upon centerings; these are drawn forward as the work proceeds.

Construction in wet or treacherous soils. — In cases where much subsoil water occurs and where hollow invert blocks are not used, it is usual to lay below the sewer a line of drain pipes to carry off the water from the front of the work; this is drained into sumps or cess-pits sunk in the line or at the side of the line of the sewer, whence it is pumped up. Care is required when laying these pipes, as they, like hollow invert blocks, may carry soil from the foundations of the sewer and thus crack it; as each portion of the sewer is finished these pipes are blocked up. When sewers have to be laid in treacherous soil, special precautions should be taken to ensure firm foundations. If a firm subsoil is a short distance below the proposed sewer level, a foundation may be obtained by throwing in road metal or gravel, until it remains on the surface, the sand or mud rising above it being removed from time to time. In other cases longitudinal timbers may have to be used and these may be covered over by planks or by layers of brushwood, &c.; on this the concrete for the sewer foundation may be laid.

Thickness of brickwork of sewers.—In England when the sewers do not exceed 3 feet in diameter and are not more than 20 feet below the surface, it is usual to build the sewers of one ring of brickwork only; in this country sufficiently non-porous bricks are not obtainable to render this plan advisable, and two rings are necessary. The following formula determines the minimum thickness of brickwork to be used :—

$$\text{viz., } \frac{dr}{100} = \text{thickness in feet,}$$

where d = depth of excavation,

and r = external radius of sewer.

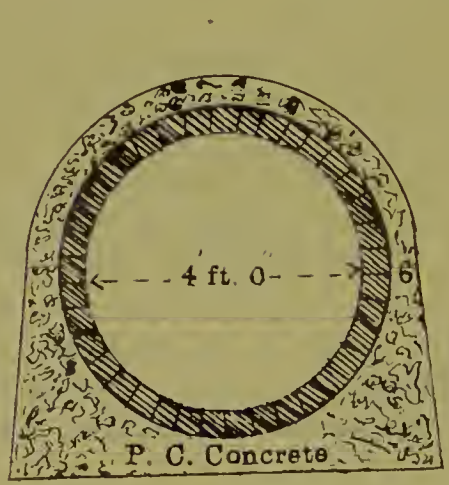
Thus, for a sewer 3 feet inside diameter and 20 feet below ground, the practice is to make the arch $4\frac{1}{2}$ inches thick, so that the outer radius would be 1·87 feet:

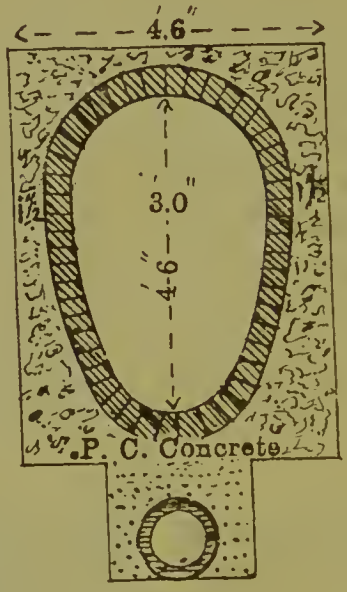
$$\frac{20 \times 1{\cdot}87}{100} = \frac{37{\cdot}4}{100} = 4\tfrac{1}{2} \text{ inches},$$

which, with good non-porous bricks, would be sufficient.

Concrete sewers.—Concrete is also used for sewers; they may be built up of concrete blocks moulded similarly (but of different shape) to invert blocks, or the sewer may be built of concrete *in situ*, if the amount of subsoil water is not very great; when built *in situ*, frames must be used into which the concrete can be tightly rammed.

Sewers are sometimes constructed of a combination of brickwork and concrete, the brickwork being a thin brick lining. The following figures are sections of some concrete sewers executed in England :—





Proportions of concrete in sewers.—In England concrete for sewers is made of one of the following proportions :—

(1) { 3 bushels of cement.
1 cubic yard of sand and shingle.

(2) { $6\frac{1}{2}$ parts clean gravel.
$2\frac{1}{2}$ parts clean sand.
1 part Portland cement.

Mixing of concrete.—The latter mixture contains to every cubic yard of concrete 2½ bushels of cement which ought to be of the best quality and should comply with conditions already laid down. The stone and gravel should be thoroughly saturated with water, for, if dry, they will extract water from the cement. On the other hand, an excess of water is to be avoided; all the materials must be thoroughly mixed and incorporated before being used.

Portland cement and soorki mortars.—Portland cement is an expensive material to use, but very fair cement is now obtainable from the Madras cement works. Cement made of soorki mortar may, however, be used in constructing sewers, especially where the sewers are cemented outside and inside and between the rings with good strong cement. Soorki mortar is hydraulic and sets very hard under water; if made of one part of soorki to one of lime paste or an equivalent quantity of slaked lime, after 28 days under water, it sets harder than the best brick.

Iron pipe sewers.—It is sometimes necessary to use iron pipes in place of circular sewers, and these may be used up to 36 inches or 48 inches in diameter; where there is a very large amount of water in the trenches, it is desirable to have as few joints as possible and to have these quickly made, turned and bored pipes are most useful. Care is required to see that the constituents of the sewage are such as will not speedily destroy the pipes and special precaution must be taken for their preservation. The thickness for such pipes cannot be determined in relation to any probable pressure on the sewers. The pipes should not be less in thickness than those used for considerable heads, in fact their weight would be limited by questions of convenience and cost where absolute security against the destructive chemical action is desired and especially where the pipes are of such size that they cannot be inspected after being laid.

Timbering trenches.—In constructing sewers in treacherous ground or where the sewers are, say, more than 5 or 6 feet below the surface, it is necessary to use timber strutting to support the sides of the excavation. Where circumstances permit, the sides of the excavation may be cut to such a slope as will allow of the work being completed without timbering, but in most cases this will be found the more expensive plan.

The following figures represent three methods of timbering trenches :—

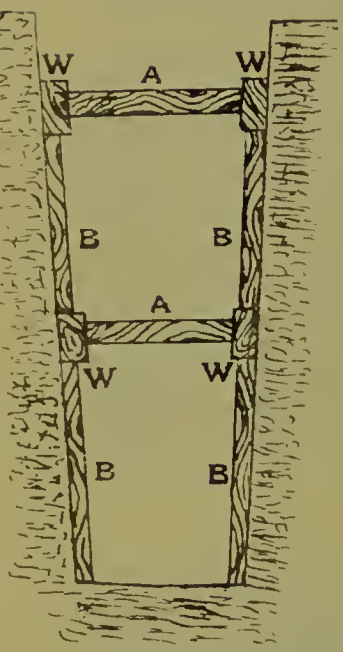


FIG. 1.

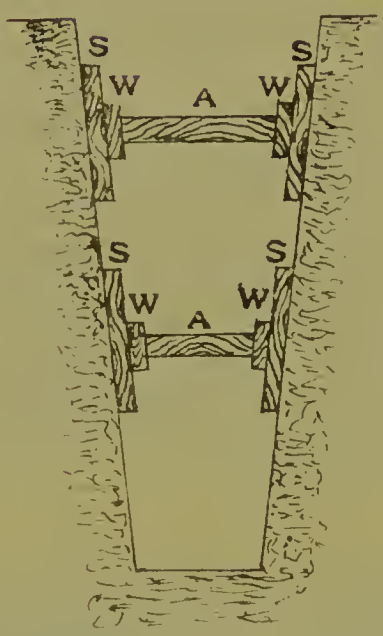


FIG. 2.

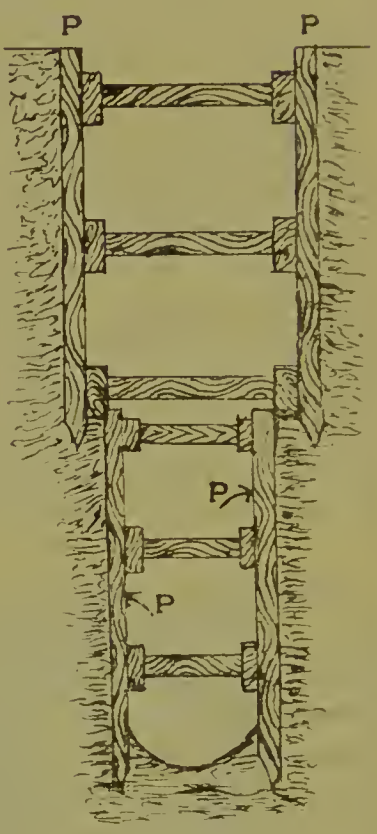


FIG. 3.

Fig. No. 1 shows the most simple mode, and is composed of walings (W), which are kept in position by the struts (A) ; in comparatively firm earth this plan may be adopted ; the pieces (B) keep the walings from slipping.

Fig. No. 2 shows a modification of the same plan ; the pieces marked (S) are called poling-boards, and it will be observed that they support a greater area of the side than in the first instance. The poling-boards are $1\frac{1}{2}$ inches thick.

Fig. No. 3 shows the system usually adopted in bad ground ; the pieces marked (P) are used as sheet-piling behind the walings.

Struts and walings to be teak.—In India for struts and walings it is advisable to use teak, but for poling-boards

or sheet-piling, mango planks 2 to 3 inches thick have been found suitable. The sides of the trenches must always be cut to a slight slope, and the struts and walings should be of such dimensions as will prevent bending when tightly wedged up. Casuarina wood makes good struts when not of greater length than 4 or 5 feet.

Sizes used in Madras.—The following sizes of timbers were used in constructing the Madras sewers, some of which are 20 to 25 feet below the surface :—

Teak struts, 8 to 12 feet by 6 inches by 4 inches.

Casuarina struts, 4 feet by 4 to 6 inches in diameter.

Walings, 6 inches by 4 inches in convenient lengths not exceeding 20 feet.

Mango planks for piling, 10 feet long, 2 inches thick, with breadths varying from 12 to 15 inches.

The struts were usually 5 feet apart longitudinally, the walings 3 to 4 feet apart vertically. Where the excavation was more than 15 feet deep, two lines of timbering were used.

Excavation in narrow streets.—In excavating through narrow streets, care is necessary, in order, that the foundations of the adjacent lines of houses may not be disturbed. The following rules obtain, in regard to the timbering of pipe sewers, in the Calcutta Municipality :—

" *Timbering of trenches.*—For all pipe sewers 2 feet struts are used, which, together with a waling piece 3 inches thick, and the piles 3 inches thick on either side, represent a cutting of 3 feet width. The trench should nevertheless not be cut to the full width to commence with, as by facing the sides to receive the piles, the cutting would become wider than 3 feet, and the struts would be found to fit loosely, requiring wedges to keep them in position. It is, however, indispensably necessary that the timbering should be perfectly rigid, the struts themselves acting as wedges, otherwise the sides of the trench would slip and cause settlement of the road surface, thus endangering the buildings adjacent to the trench."

" To attain the requisite rigidity of the timbering, it is necessary that the trench be cut only 2 feet 9 inches wide to begin with, the $1\frac{1}{2}$ inches on either side being obtained by carefully facing the sides of the trench preparatory to the

insertion of the piles, &c. The timbering should always be put as soon as practicable, and invariably before cutting deeper than 4 feet, except in cases where, in consideration of very good soil or shallow sewers, the Superintendent may feel justified in dispensing with piling altogether. In all narrow streets and lanes the trenches must not be cut in continuous lengths; benches not less than 2 feet wide must be left at short intervals, to guard against sinkage and possible damage to buildings."

FLUSHING WORKS.

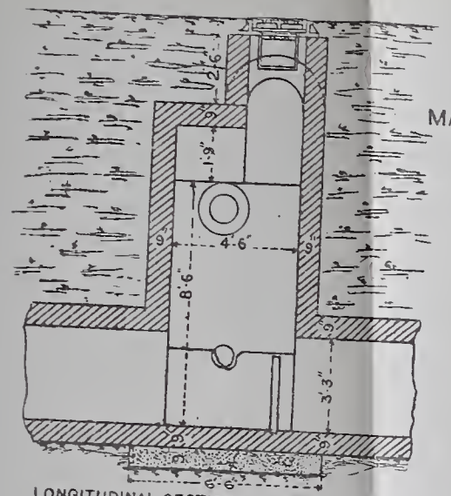
Flushing necessary.—When constructing sewers it is advisable in all cases to make arrangements for flushing them. A certain velocity of flow is, as has been shown, necessary to prevent deposit; but as all sewers must be subject to variation of flow, any retardation will lead to deposit.

Operation of flushing.—Many plans have been adopted for flushing, the object in all cases being to send a large body of water through the sewer at a considerable velocity.

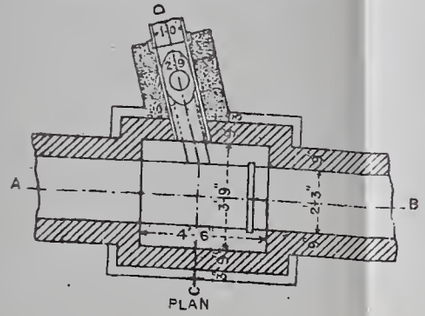
One of the more simple methods to effect this is to dam up the sewer and suddenly liberate the sewage so backed up. On plate accompanying will be found a sketch of a man-hole with flushing door. It will be observed that there is a space between the flushing door and the portion of sewer backed up; this is for two purposes, *firstly*, to guard against over-pressure in the sewer should the boards be left carelessly in by the flusher; *secondly*, to prevent so great a pressure against the board that it could not be lifted, the sewage when its surface becomes level with top of the board flowing over it.

Flushing syphon.—A convenient method of flushing is that shown in the diagram accompanying. The filling of the tank is regulated so that it may be filled in one, two, five or any other number of hours. It is only when the water arrives at the level of the top of the inner of the two vertical pipes, that it is discharged automatically by means of the syphon arrangement. The arrangement shown in the diagram is that for the head or highest point of a sewer, but the same design is easily adapted to any point on the line of sewer, in which case the pipe shown would be a branch pipe into the main sewer, the flushing chamber being at some distance from the side of the sewer.

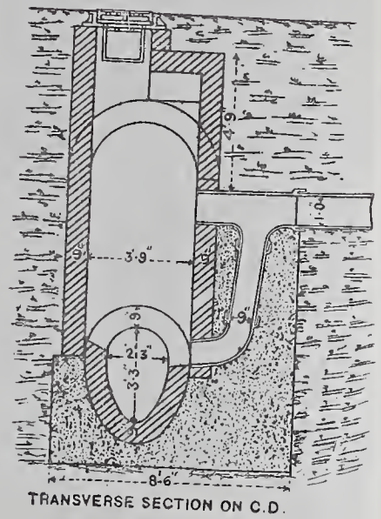
DESIGN FOR A MANHOLE ON BRICK SEWER



LONGITUDINAL SECTION ON A.B.



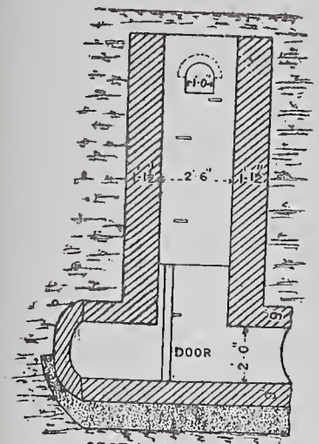
PLAN



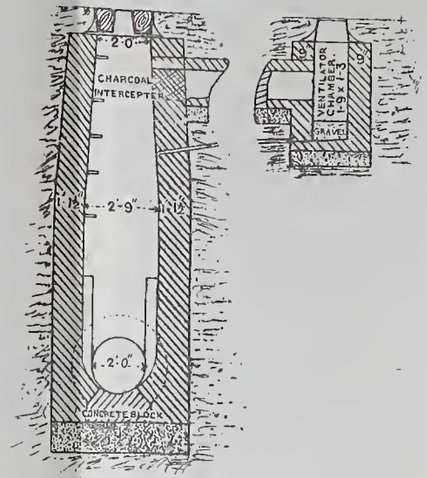
TRANSVERSE SECTION ON C.D.

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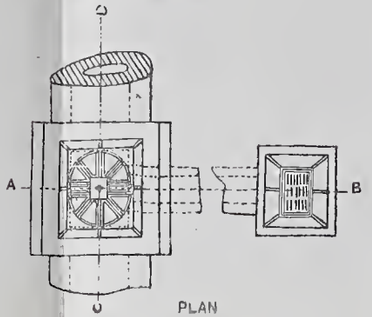
DESIGN FOR A MANHOLE AND VENTILATOR ON BRICK SEWER



SECTION ON C.D.

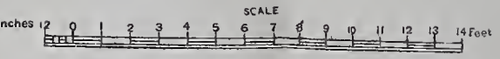


SECTION ON A.B.



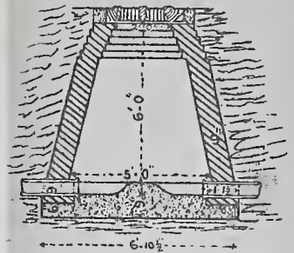
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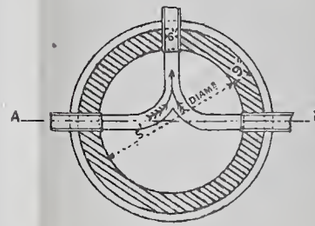
SAMPLES OF MANHOLES



DESIGN FOR A MANHOLE ON PIPE SEWER

SECTION ON A.B.





PLAN

SECTION OF A MANHOLE ON PIPE SEWER

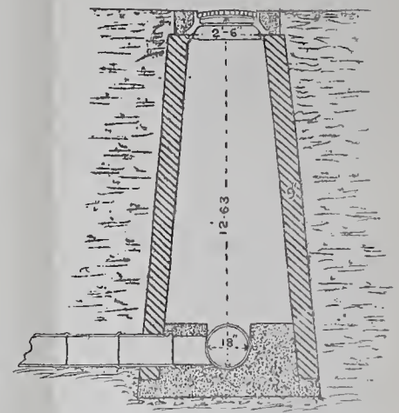
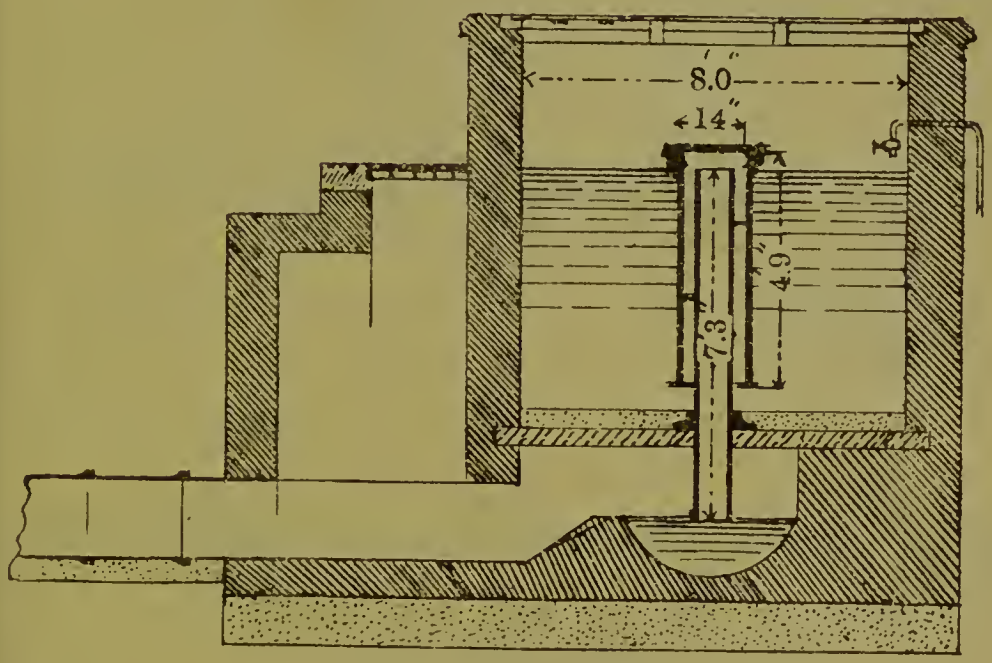


Photo-Zinco, Survey Office, Madras

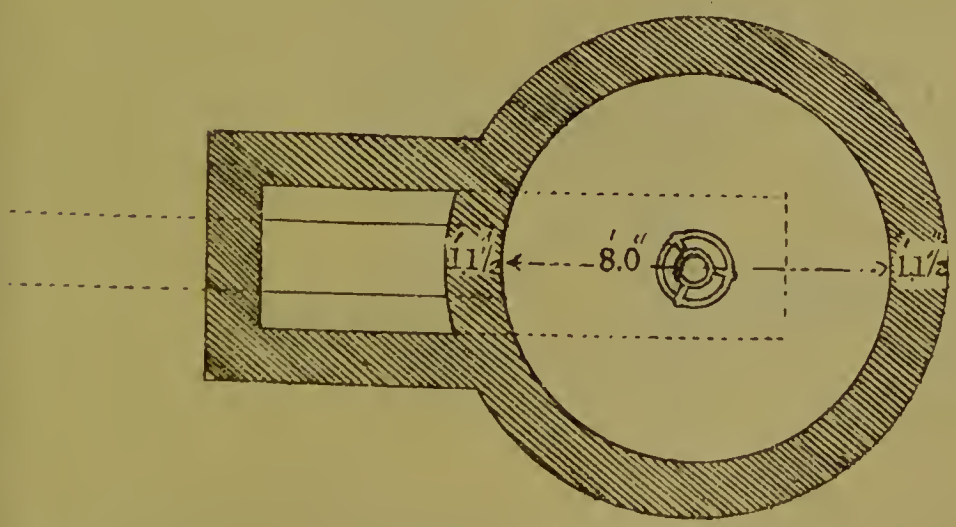
FIELDS

AUTOMATIC SYPHON AND FLUSHING TANK

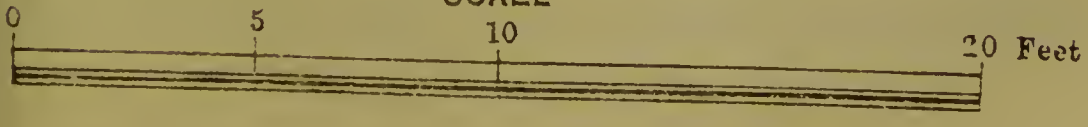
SECTION



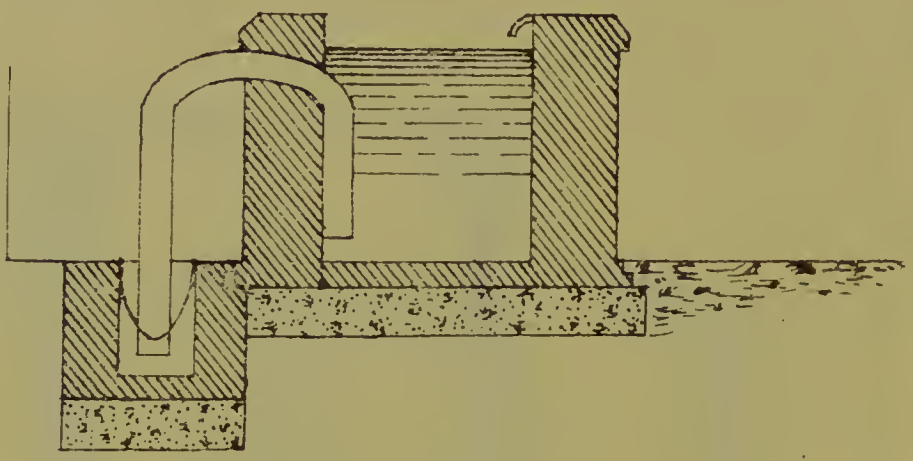
PLAN



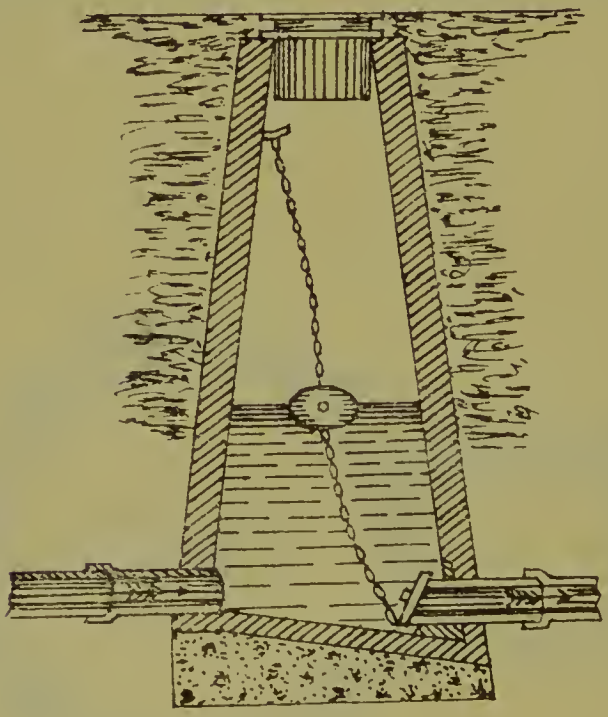
SCALE



Syphon for flushing surface drains.—The following is an adaptation useful in case of a surface drain, and consists of a long tank, with a syphon outlet placed between the side of the drain and the street :—



Arrangement for flushing pipe sewers.—A plan adopted by Mr. Baldwin Latham is shown below :—



When it is desired to flush the sewer a wooden block is placed on the end of the pipe issuing from the man-hole, and

when sufficient sewage has accumulated, the block is removed by pulling the chain. The use of the float shown on the chain is to prevent, in case of negligence, the water in the man-hole rising too high and thus tending to burst the upper part of the sewer, as when the float has risen so as to make the lower part of the chain tight, any further rise will remove the block and allow of the discharge.

It is not necessary to enumerate or give sketches of more of the many appliances invented to serve the same purpose; those above given seem to be the most suitable for India, and, at the same time, the least expensive.

In selecting an automatic flush tank the requisites are (1) certainty of action, (2) rapidity of discharge, (3) simplicity of construction, (4) ease of inspection, (5) durability, (6) economy in cost and maintenance.

Flushing from hydrants.—Small sewers may be flushed by water led into them by a hose direct from hydrants on the water mains, or they may be filled by water run from picottahs.

VENTILATION OF SEWERS, MANHOLES, TRAPS, &c.

Ventilation of sewers a necessity.—One of the greatest difficulties in regard to sewer construction is to ventilate them without constituting them a nuisance; that they must be ventilated is evident, or the gas would force its way into the houses or through tributary sewers until it reached some outlet.

The methods of ventilation suggested, from time to time, are exceedingly numerous, and the following are selected as examples of those more generally used. The system which has found most favour is that in which shafts are carried up from the crown of the sewer as in plate facing page, 456. The ventilation takes place through the iron grid or grating at the road-level. It will be observed that this ventilator is combined with a man-hole, and the reason why it is not placed directly over the man-hole is to prevent sweepings and road grit entering the sewer; any such material would be arrested in the pit during rainfall, also, when the surface of the road probably becomes muddy, the road detritus is arrested and excluded from the sewers. In the arch a charcoal ventilator may be placed, so that all gas passing out of the sewer is in a measure disinfected before reaching the open air of the street.

Position of ventilating grids.—Where the sewers are not intended to carry off rainfall, these ventilating grids

should, as far as possible, be placed in the centre or highest portion of the road, as then only the rain falling on the area of the grid is likely to enter the sewer. This is also the best position in another respect, any gas passing into the air as far as possible from the adjacent houses.

Objections to foregoing plan.—The objections to this plan are (1) that passengers are occasionally annoyed by the escaping gas; (2) that downcast currents may occur driving the sewer gas to house drains or other sewage inlets; (3) that the situation of the grids is awkward for traffic, and horses detest them.

Ventilation by pipes up the sides of houses.—Another system is that by which the air is carried from the shafts above the sewers by long pipes which pass under the road and up the sides of houses where the air is discharged above the level of the roof. The objections to this system are that the distance the sewer gas has to travel is comparatively great; that difficulty is often found in constructing the shafts where required; that house-owners object to them, and rightly so, because if leakage takes place, the gas is apt to enter the house. There are other methods, such as ventilation through lamp-posts, house chimneys, &c., but none of these are suitable for this country.

Ventilation at street level most convenient.—Ventilation at the level of the street has been found the most convenient, as well as the most economical plan, and much attention has, therefore, been directed to the consideration of plans for the deodorization of the gases before reaching the grids.

Purification of gas by charcoal.—One method is that of passing the gases through charcoal, and the most eminent authorities agree that charcoal traps are most efficient air purifiers when properly arranged.

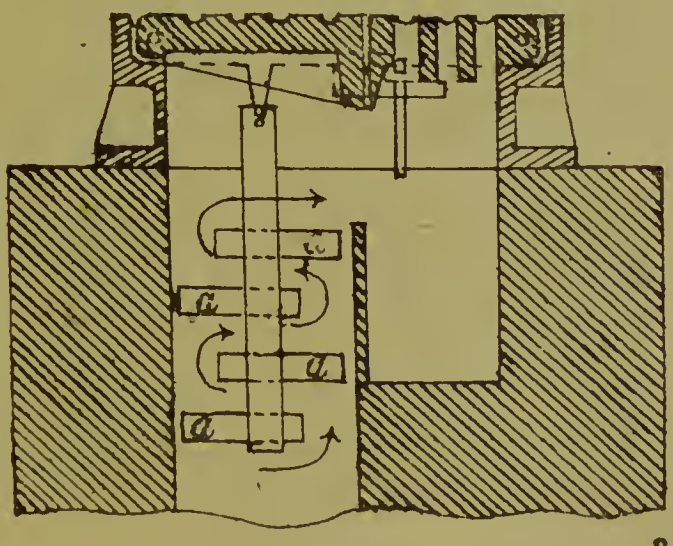
The following table shows the quantity of gas in centimeters absorbed by half a gramme of different varieties of charcoal:—

Kind of charcoal.	Ammonia.	Hydrochloric acid.	Sulphuretted hydrogen.	Carbonic acid.	Oxygen.	Sulphurous acid.
Wood ...	98·5	45·0	30·0	14·0	0·8	32·5
Peat ...	96·0	60·0	28·5	10·0	0·6	27·5
Animal.	43·5	...	9·0	5·0	0·5	17·5

Action of charcoal described.—The absorbing powers of charcoal, it will be observed, are very great. Dr. Volecker, F.R.S., says of it that "it possesses the power not only of absorbing certain smelling gases, sulphuretted hydrogen and ammonia, but also of destroying the gases absorbed, for otherwise its purifying action would be soon greatly impaired. It is very porous, and its pores are filled with condensed oxygen to the extent of eight times its bulk. We have, therefore, in charcoal, oxygen gas (which supports combustion) in a condensed or more active condition than in common air which we breathe. Hence it is that organic matter in contact with charcoal is so rapidly destroyed. The beauty of charcoal is that the destruction takes place imperceptibly, and that its power of burning organic matter is continually renewed by the surrounding atmosphere, so that it is a constant carrier of atmospheric oxygen in a condensed state into its pores. The oxygen that acts on organic matter and burns it up is speedily replaced, and the process goes on continually. Hence it is that a comparatively small quantity of wood or peat charcoal is capable of destroying a large quantity of organic matter."

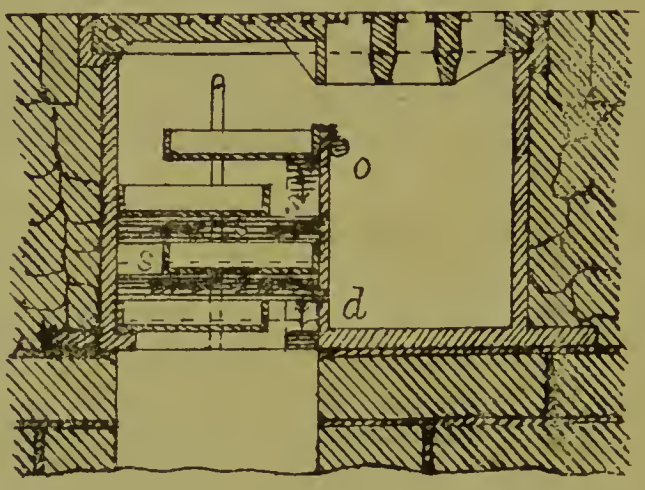
Charcoal to be kept dry.—When charcoal can be kept dry, its absorbent power will continue very much longer than when it is exposed to wet or damp, and in placing charcoal ventilators in sewer shafts, arrangements should always be made to keep them as clear of water as possible. In the sketch given on plate accompanying, the water, it will be observed, filters through the material at the bottom of the ventilator pit and is discharged into the sewer pit; but even under this plan the charcoal is apt to get wet in heavy rainfall.

A plan in common use is that shown in the following diagram:—



Charcoal tray ventilator.—The trays of charcoal are marked (*a*), and the sewer gas passes up in the direction of the arrows over the trays, and is disinfected by absorption during its passage between the trays. This plan has, however, the same defect as the one formerly referred to, viz., the liability of the charcoal to get wet.

Baldwin Latham's ventilator.—The following figure shows an improved plan by which water having risen so as to overflow the box (*d*) passes out by the overflow pipes (*o*), and is conveyed away by the route *s s* to the sewer. The trays in this case block the whole shaft, so that no gas escapes without passing through the charcoal :—



Number and area of ventilators necessary.—The number of ventilators should bear a constant ratio to the capacity of the sewers, and the sum of the total discharge from the ventilators on a sewer should not be less than the discharging capacity of the sewer. The discharge through the ventilators varies with the difference of the temperature

---

NOTE.—In Buck's *Hygiene*, Dr. Ford, President of the Board of Health of Philadelphia, writes: Notwithstanding the advantages claimed by Latham for this kind of ventilator (charcoal ventilator), the verdict of the most experienced engineers is now pronounced against its general use. Charcoal is "so often an evil rather than a benefit that as a rule, it ought to be discarded from sewerage systems" (Denton). Any device that obstructs the free circulation of air in and out of the sewer is objectionable. The greatest possible dilution of the sewer air is the object to be aimed at, and this can be obtained by providing a sufficient number of openings at man-holes, lamp-holes, &c.

in the sewer and that at the exit level and may be calculated as follows :—

H = height of shaft in feet,
T = temperature of air in sewer,
t = do. street,
V = velocity in feet per second,
a = ·0020361 for Fah. ·003665 for Centigrade,
then $V = 8\sqrt{Ha\,(T-t)}$.

Consider a sewer, with a discharging capacity of 600 feet per minute, the length of which is 7,000 feet; suppose that there is a ventilator at every 150 feet, then we have $\frac{7000}{150} = 46$ ventilators, and according to the rule enunciated the total discharge from the ventilators must be 600 feet or 13 cubic feet per minute from each ventilator; suppose the ventilating shafts, 16 feet high, and the minimum difference of the temperature to be, say 4° F., then

$$V = 8\sqrt{16 \times ·0020361 \times 4}$$
$$= 8 \times ·36 = 2·88 \text{ per second}$$
$$= 172·8 \text{ feet per minute.}$$

Each ventilating grid would, therefore, require to have an area of $\frac{13 \times 144}{173} = 10·8$ square inches. The ventilators ought in no case to be more than 150 feet to 200 feet apart: they ought to be closer at the lower ends of the sewers than at the upper.

If the direction of the flow of air were dependent entirely on the fact of the temperature of the atmosphere being greater or less than that of the air in the sewer, the flow would be sometimes into the sewer and not out of it. From experiments made at Wimbledon in 1888, it was found that wind is the most powerful agent in creating air currents in and from sewers, and that the flow of air was sometimes in the same direction as the flow of sewage and sometimes the reverse. In a town the direction of the wind is very varied, it being deflected by the obstructions with which it meets. This factor is also one that tends to ensure ventilation.

One word of caution is necessary in regard to the action to be adopted in case of complaints regarding nuisances caused by sewer ventilators, and that is never to close a ventilator unless another can be opened in a more suitable

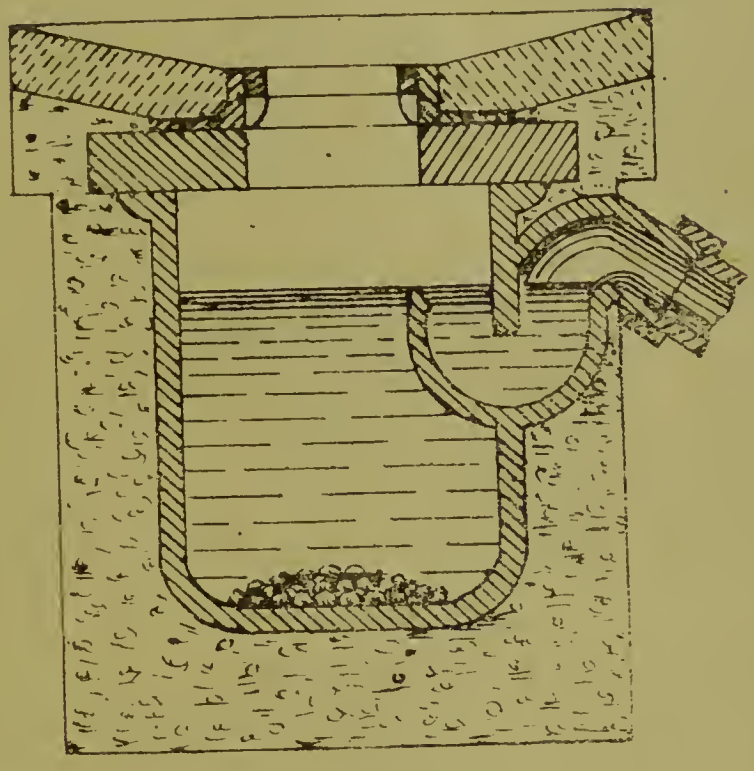
locality. Dr. Carpenter, at the Social Science Congress in 1889, on the influence of sewer gas on public health, said: "when a stink is perceived at a particular spot or in a particular house, orders are usually given to stop the place of issue by trapping the offending opening with the beneficial result of staying the progress of the disease in that particular place, but no means are taken to prevent its influence being felt elsewhere. The mischief is simply transferred in a selfish kind of way from one place to another and the public suffers. Trapping is not the proper remedy unless accompanied by the provision of another exit in a safer situation."

Man-holes and lamp-holes.—The former should be amply provided on sewers, for purposes of entry and inspection, the latter also for inspection purposes only. The man-holes provided on modern sewers are usually square or round wells steined with brickwork and furnished with iron steps, so that men can descend into the sewers. Plans and sections of man-holes combined with ventilators are to be found on the plate facing page 456. They may be covered with iron plates or stone. Man-holes are usually made to act as ventilating shafts, and thus serve a double purpose. Lamp-holes are shafts which may also be put to a similar use; they do not allow of the entry of men, but a lamp can be lowered through them into the sewer by which the state of the sewer between a lamp-hole and an adjoining man-hole may be ascertained.

Side entrances.—Where it would be inconvenient to frequently open up a street for entry to the man-holes, side entrances to the sewer are provided, a man-hole being placed there of less depth than the height from the sewer to the street surface, the two levels being connected by steps. The bottom of a man-hole is often formed into a cesspit, and these, in the construction of sewers, have been found of great advantage, as they can be used for pump wells and for receiving the discharge of the pipes running under the sewers.

Use of gullies and traps.—When the rainfall or a portion thereof is to be admitted to the sewer, certain arrangements are necessary (1) to prevent the admission of sand, (2) to prevent the emission of sewer gas. The first is effected by a gully, the second by what is called a trap or barrier between the sewer on one side and the air of the streets or houses on the other.

The following diagram shows a simple form of trapped gully :—



Causes of occasional failures of action of traps.—Water traps are usually constructed on the principle of the inverted syphon; in the smaller sizes they often become ineffective through being completely emptied by the syphon discharging full bore and emptying the trap. Evaporation is another cause of failure and one likely to be often met with in India. There are, however, numberless descriptions of traps and gullies as any sanitary plumber's catalogue will testify; it is impracticable here to enumerate or describe them.

HOUSE DRAINAGE.

In certain large towns in India, such as Bombay and Calcutta, underground sewerage systems have been introduced and the house drains are connected with these underground sewers. Generally the drains from the sewer to the house end in a trap placed outside the house. In many cases, the sullage waters from the house are passed from the house by pipes to open drains which convey the sullage to the trap before mentioned. Certain houses in Bombay and Calcutta

have water closets, and where these are in use closed pipes are necessary on either side of the trap.

Exclusion of sewer gas.—Where houses have water closets or have for some other reasons closed drains in connection with the sewers, a way is open for the passage of sewer gas into the houses and the most elaborate precautions are necessary in the way of traps and ventilation to prevent its entry. In India where the evolution of sewer gas is so rapid, the danger due to the admission of sewer gas into houses is a matter which calls for very carefully considered precautions. Again, in India, where the great majority of the houses in a town are of such low value that any extra taxation necessary to pay for special apparatus would often cause a house to be vacated, the difficulty of securing the provision of such apparatus is very great. If a house has a water closet, it must have its own connection with the sewer; if the excreta is otherwise disposed of, then a block or row of houses may be furnished with open drains to carry off the sullage water to the sewers and one connection only properly trapped and ventilated may be required.

Bombay house connections.—In Bombay, or at any rate in large areas of it, the corporation considered it necessary to construct at their own cost the house connections necessary, requiring only that the owner should thereafter keep them in order. Even this is really not effectually done, and a committee sat in Bombay in 1892 to consider the whole question of house connections. In the evidence given, there are found such statements as this, "they force all sorts of things into the down-take pipes, food, leaf plates, ashes, sand, earth and besides that the nahani connections are used for urinating and defœcating. I have seen holes in syphons and discharge pipes and pieces of down pipe taken away." The system adopted in Bombay is to carry down pipes from a sink placed outside a window down the side of the house; these pipes end and discharge over a trap at ground level, and thence either an open or underground drain carries off the sullage water to the sewer. There is a syphon on the down pipe. There is no doubt that an open surface drain between the house and the sewer is advantageous, because any solid substance will be arrested and a surface drain can be easily cleaned. Where there are water closets in use, open drains cannot be used, and more elaborate systems of trapping and ventilation are imperative.

Difficulties in providing effective house drainage.—In India as in England the proper design and provision

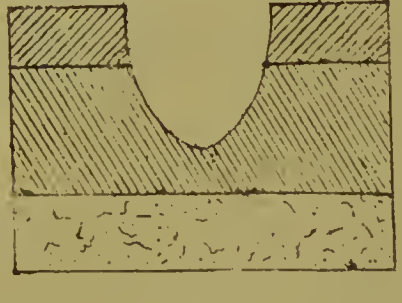
of house drains is the most difficult point in all drainage schemes; upon the skill shown in their arrangement, construction and ventilation, the marked effect of drainage works will depend. But it is the author's opinion, looking to the difficulties in finance, ignorance of sanitary requirements and sanitary apparatus and their use, the want of proper, sufficient and intelligent labour, the dangers of ill-construction, that water closets should never be introduced into Indian houses, and that any drains in connection with the sewers for carrying away sullage water should end outside the house and if possible some distance from it. The diagram on the following page shows the manner in which the drains and connections from inside the house are disconnected from those outside. Pipes other than soil pipes discharge over the top of the grating.

Cost of house connections.—The cost of house connections will average in India not less than Rs. 100 a house, and in many houses will be two and three times that amount.

STREET DRAINAGE.

Open street drains.—Street drains are constructed for carrying off sewage and storm water or for the latter only. When a town has sewers to which the house drains are connected, sewage does not enter the street drains, and these are then for storm waters alone, but in towns, where an underground sewerage system does not exist, or where sewers are in the main streets only, the house drains are not in direct communication with the sewers, and the sewage is discharged into the street drains. These drains in India are usually the first attempt at drainage of any description whatever, and where sufficient slope can be obtained, they are of much benefit in removing sewage from the immediate neighbourhood of dwellings.

Form of section of street drains.—Many sections of street drains have been proposed and adopted, but when it is considered that they have to carry at one time sewage, and at another the sewage mixed with large quantities of storm water, it is evident that these drains ought to be of an oval section, that being the section most suited for varying discharges. The following sections



CONNECTION OF HOUSE DRAINS WITH SEWERS

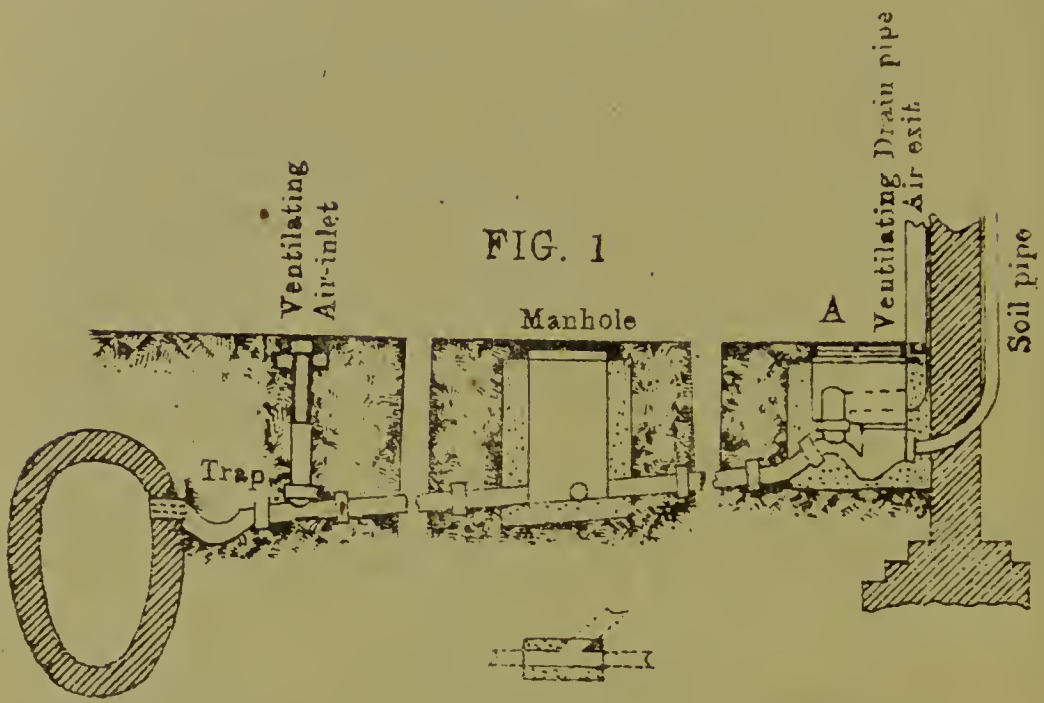


FIG. 1

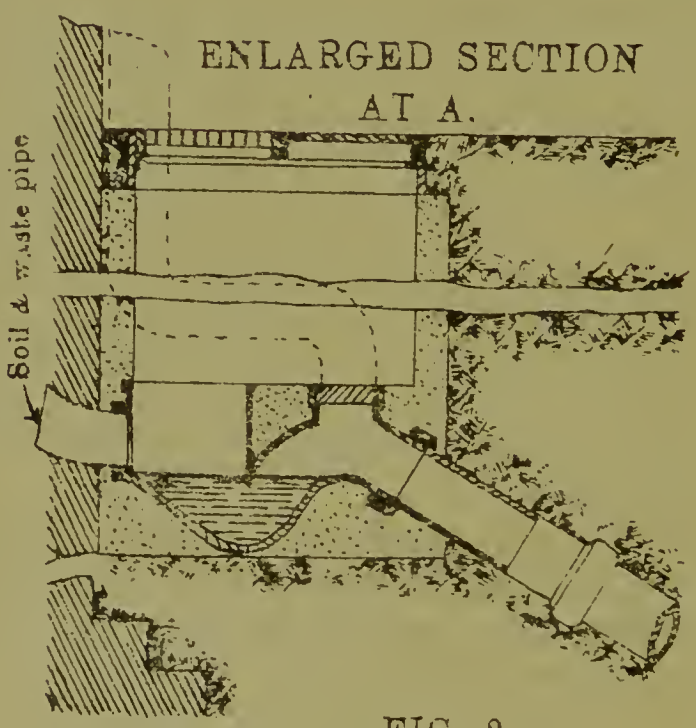
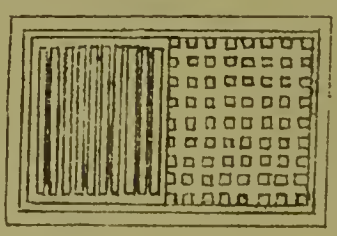
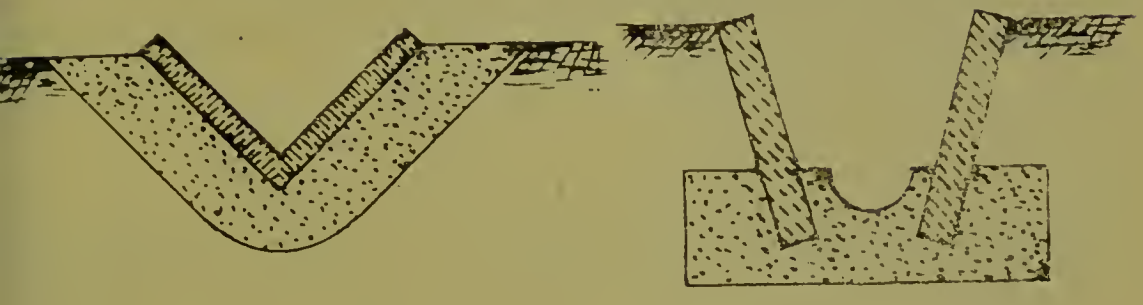


FIG. 2

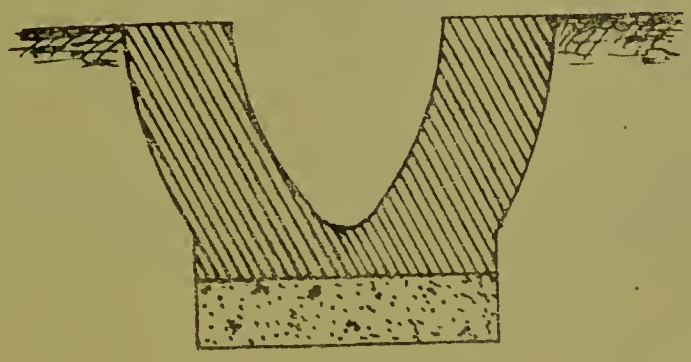


Inches 12 0 1 2 3 Feet

have been advocated as suitable to the wants of South Indian



towns, but being partly composed of Cuddapah or slate slabs are easily broken and not so easily cleaned as in the former section. The section first given may be modified thus; in this form less cutting of bricks is required.

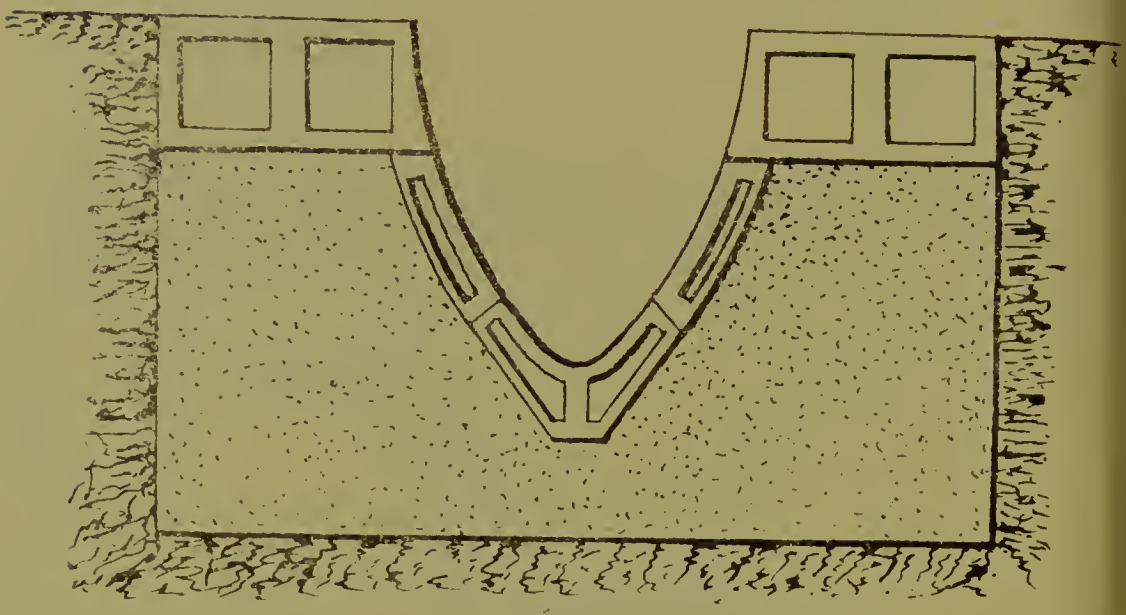


For side streets, lanes and backyards, the author has found the following sections of drain most convenient and cheap. It is formed of stoneware tiles made by Messrs. Burn and Co.



When inverted, they form very useful drains for filter beds (*vide* chapter No. VII).

The following diagram shows a drain of a more expensive character, but superior in construction to any of the above, the inside being formed of glazed tiles, the backing being concrete :—



The following tables give the velocities and discharges of drains of the ovoid section running full ; they should be laid at such gradients as will ensure that the ordinary depth of sewage flow has a velocity sufficient to keep them clear ; this is not easy to effect where the town is on a flat site or where streets run along the contours of a hill, but all drainage works must be really more or less of a compromise with regard to the most perfect conditions, and open street or surface drainage is all that a town may be able to afford :—

Velocity and discharge in feet per minute of open drains ovoid section (in which the depth is equal to the top width and the invert has a radius of $\frac{1}{8}$th of the top width) when running full and at various rates of inclination.

Inclination.	Velocity in L. ft.									Discharge in cub. ft.								
	Size of drains.									Size of drains.								
	6″	9″	12″	15″	18″	21″	24″	27″	30″	6″	9″	12″	15″	18″	21″	24″	27″	30″
1 in 50 ...	313	384	443							57	156	320						
1 in 55 ...	299	366	423							54	149	305						
1 in 60 ...	286	350	405							52	142	292						
1 in 65 ...	275	337	389							50	137	281						
1 in 70 ...	265	324	375							48	132	271						
1 in 75 ...	256	313	362	404	443	479				46	127	261	456	720	1,059			
1 in 80 ...	247	303	350	392	429	463				45	123	253	442	697	1,025			
1 in 85 ...	240	294	340	380	416	450				43	120	246	429	677	995			
1 in 90 ...	234	286	330	369	405	437				42	116	239	417	658	967			
1 in 95 ...	227	278	322	359	394	425				41	113	232	406	640	941			
1 in 100 ...	222	271	313	350	384	415	443	470	496	40	110	226	395	624	917	1,280	1,722	2,237
1 in 110 ...	211	259	299	334	366	395	423	448	472	38	105	216	377	595	874	1,221	1,642	2,133
1 in 120 ...	202	248	286	320	350	378	405	429	452	37	101	207	361	569	837	1,169	1,572	2,042
1 in 130 ...	194	238	275	307	337	364	389	422	435	35	97	199	347	547	804	1,123	1,546	1,962
1 in 140 ...	187	229	265	296	324	350	375	397	419	34	93	191	334	527	775	1,082	1,456	1,891
1 in 150 ...	181	222	256	286	313	338	362	384	405	33	90	185	323	509	749	1,045	1,406	1,826
1 in 160 ...	175	215	248	277	303	328	350	372	392	32	87	179	313	493	725	1,012	1,362	1,768
1 in 170 ...	170	208	240	269	294	318	340	361	380	31	85	174	303	478	703	982	1,318	1,716
1 in 180 ...	165	202	234	261	286	309	330	350	369	30	82	169	295	465	684	954	1,281	1,667
1 in 190 ...	161	197	227	254	278	301	322	341	359	29	80	164	287	453	665	929	1,247	1,623
1 in 200 ...	157	192	222	248	271	291	313	332	350	28	78	160	280	441	648	905	1,215	1,581
1 in 220 ...	149	183	211	236	259	279	299	317	334	27	74	153	267	421	618	863	1,159	1,508
1 in 240 ...	143	175	202	226	248	268	286	303	320	26	71	146	255	403	592	827	1,110	1,443
1 in 260 ...	137	168	194	217	238	257	275	292	307	25	68	140	245	387	569	794	1,066	1,387

Velocity and discharge in feet per minute of open drains ovoid section (in which the depth is equal to the top width and the invert has a radius of $\frac{1}{8}$th of the top width) when running full and at various rates of inclination—cont.

Inclination.	Velocity in L. ft.									Discharge in cub. ft.								
	Size of drains.									Size of drains.								
	6″	9″	12″	15″	18″	21″	24″	27″	30″	6″	9″	12″	15″	18″	21″	24″	27″	30″
1 in 280 ...	133	162	187	209	229	248	265	281	296	24	66	135	236	373	548	765	1,027	1,337
1 in 300 ...		157	180	202	222	239	256	271	286		64	131	228	360	529	739	992	1,292
1 in 325 ...		151	174	194	213	230	245	261	275		61	126	219	346	509	710	953	1,241
1 in 350 ...		145	167	187	205	222	237	251	265		59	121	211	333	490	684	919	1,196
1 in 375 ...		140	162	181	198	214	229	243	256		57	117	204	322	474	661	888	1,155
1 in 400 ...		136	157	175	192	207	222	235	248		55	113	198	312	459	640	859	1,118
1 in 425 ..			152	170	186	201	215	228	240			110	192	303	445	621	834	1,085
1 in 450 ...			148	165	181	195	209	222	234			107	186	294	432	604	810	1,055
1 in 475 ...			144	161	176	190	203	216	227			104	181	286	421	588	789	1,026
1 in 500 ...			140	157	172	185	198	210	222			101	177	279	410	573	769	1,000
1 in 550 ...			134	149	164	178	189	200	211			97	169	266	391	546	733	954
1 in 600 ...				143	157	169	181	192	202				161	255	374	523	702	913
1 in 650 ...				137	151	163	174	184	194				155	245	360	502	674	877
1 in 700 ...				132	145	157	167	178	187				149	236	347	484	650	846
1 in 750 ...					140	151	162	172	181					228	335	468	628	817
1 in 800 ...					136	147	157	166	175					220	324	453	608	791
1 in 850 ...						142	152	161	170						315	439	590	767
1 in 900 ...						138	148	157	165						306	427	573	746
1 in 950 ...						135	144	153	161						298	415	558	726
1 in 1,000 ...							140	149	157							405	544	707
1 in 1,100 ...							134	142	149							386	519	674
1 in 1,200 ...								136	143								497	646
1 in 1,300 ...									137									620
1 in 1,400 ...									132									598

Area and hydraulic mean depth of ovoid drains (in which the depth is equal to the top width and the invert has a radius of $\frac{1}{8}$th the top width).

Size of drain.	Sectional area.	Hydraulic mean depth.	Remarks.
	SQ.FT.	FEET.	
6″	·1806	·1537	
9″	·4063	·2306	If a = top width = depth of drain and $\frac{a}{8}$ = radius of invert, then $\frac{4a}{3}$ = radius of side arc.
12″	·7223	·3074	
15″	1·1287	·3843	
18″	1·6253	·4611	
21″	2·2122	·5380	
24″	2·8894	·6148	
27″	3·6568	·6917	
30″	4·5146	·7686	

Construction of street drains.—The concrete floor or brick foundation should not have footings; in the first place they are unlikely to be required to aid in the distribution of the weight of the drain, which weight is extremely small, and such footings would require a wider trench than necessary, or an unsatisfactory form of excavation. The fact of the trench being cut exactly to the width required for the drain adds much to its strength.

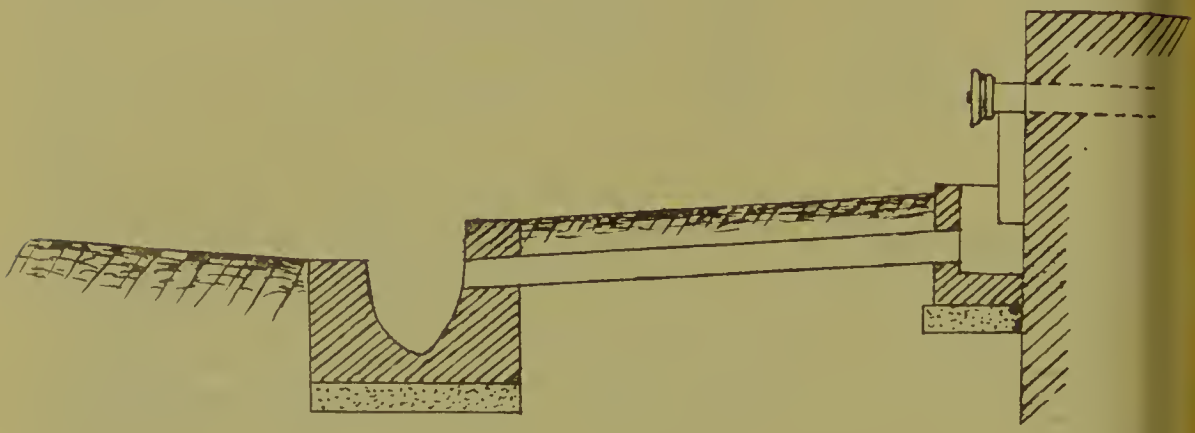
Materials for constructing street drains.—These drains may be of brick in soorki or cement capped by hard burnt bricks, by stone where available. They should be lined with cement plaster not only to give them a smooth surface, but because the sewage tends to destroy the mortar between the bricks, and finally the bricks themselves. Where glazed tiles are used for lining the drains they should be set in cement, but the concrete may be formed with ordinary or soorki mortar.

Requirements in designing street drainage.—All street drains should be constructed on some pre-arranged plan, because whether an underground sewerage system exists or whether one is to be afterwards adopted, these street drains will still be required. They should, therefore, be designed so as (1) to carry the rainfall to existing outfalls and perhaps, it may be necessary to carry the sewage there also at first, and (2) to discharge their sewage contents into existing or

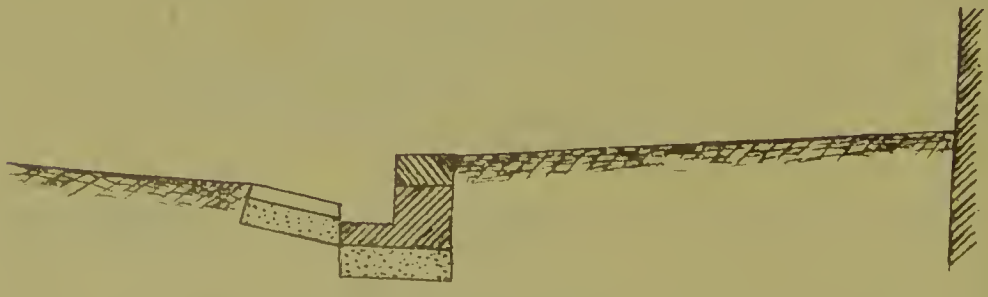
proposed underground sewers. The capacity of drains from the higher parts of the town must be increased gradually, as they receive tributary drains and approach the lower parts towards their point of discharge.

Maximum rainfall cannot be provided for.—Their discharging powers must be calculated on some fixed amount of rainfall, say, half an inch per hour. This is not likely to be the maximum rainfall to be carried off, but in India, it is almost impossible to make provision for rainfall of the greatest known intensity.

Position of street drains.—The drains may be close to the houses or may be, if footpaths exist, between the footpath and the road, thus—



Where drains are for water from the street alone, a deep section like the above is not necessary, and a common method is to form the drain along the footpath in the following manner:—



Arrangements at street crossings.—At street crossings and house entrances more headway than that required for the actual depth of the drain ought to be given, to allow of the drains being cleaned and any solid matter

removed. Open drains under street crossings ought not to be arched over, but covered with flat stones, as when an obstruction does take place, one or two stones can be easily removed and replaced, while rebuilding a portion of an arch is always a matter of some difficulty.

Objections to open drains.—One objection to open street drains has been already noticed, viz., the difficulty of always obtaining proper gradients for the drains. There are other objections to them, viz., that they are apt to be blocked by solids for which they are not intended being passed into or placed in them. Again, the house drains often discharge excreta along with sullage water, if the house drain is in a convenient situation for the reception of the former or if the privies are badly constructed. Against these objections may be placed the fact that, if the drains are blocked, it is known where they require cleaning and that they can and ought to be cleaned daily, that their contents are ever subjected to influence of air and sun, and that under the open system there is no way opened for the admission of sewer gas into the houses. A few further remarks on street drains will be found in the account of the drainage of Black Town of Madras. The drainage, which at present obtains in Indian houses, is also further referred to.

OTHER SYSTEMS OF DRAINAGE.

The Lierneur and Shone systems of drainage, &c.—So far, what is known as the water carriage system of drainage has alone been mentioned, but there are other systems; two of the most notable are those just mentioned.

The Lierneur system.—Some years ago, a Dutch Engineer, Captain Lierneur, proposed an entirely new plan, which is one under which the excrementitious products are taken direct from the houses by means of pipes, from which the air is exhausted (the extracting force being equal to 1,500 lb. on the square foot), and the excreta is thus drawn to central stations where it is transferred to air-tight carts. These are transported to the place where the manurial products are to be utilized. The system pre-supposes a town fitted with closets of an improved description and is unsuitable for India.

The Shone system is suitable for places with flat gradients, and the system is one that must, as time goes on, find favour in India. It is the one, on which the town of Rangoon has been drained, and is most suitable for towns built on nearly level plains and for places which are little

above sea or river level. In such places proper gradients for the sewers cannot be obtained without deep excavations or numerous pumping stations; by the Shone system good gradients may be secured and deep excavations avoided. It is also comparatively cheap.

Compression by air part of Shone system.—The system may be thus briefly described. It is the opposite of Captain Liernеur's system, the agent being the compression instead of the exhaustion of air, and it is additional to the ordinary water carriage system of sewage, and not in substitution for it.

Advantages of the system.—Where towns are situated, so that they stand little above the level of surrounding plains or a neighbouring sea-board, where, perhaps, the rise and fall of the tide may be insignificant, or where, as at Rangoon, a city is built on the delta of a great river and the execution of deep sewers is a very expensive undertaking, the difficulties which engineers experience in designing economical and suitable drainage works can hardly be comprehended by their non-professional brethren. The difference between sanitary and insanitary drainage works lies in this, that while the former dispose of the sewage before it throws off those obnoxious gases which bring both discomfort and disease, the latter class generally, for want of conditions favourable to gravitation, fail in their allotted task. No part of engineering science has been more carefully investigated than that relating to the laws which govern the flow of water in pipes and channels, and a velocity of not less than $2\frac{1}{2}$ feet per second is desirable in all sewers to prevent deposit. Seeing, then, that engineers have only to design their works so that when the sewage enters them it shall pass along at the above velocity, the uninitiated naturally ask, "why not insist on every Sanitary Engineer designing such works as shall comply with these conditions?" It may, however, be easily comprehended that if, in towns such as have been described, the precepts laid down were carried out, the sewers at their lower ends would be much below ground and without any outfall and expensive pumping works would be necessary to complete such a scheme. Engineers have been driven in many cases to lay down sewers at such levels and gradients as are not free from objection, but which, though not efficient, are much in advance of pre-existing sanitary conditions. The Shone system affords means by which outlay on deep sewers may be avoided, and at the same time it allows of the removal of sewage in an efficacious and simple manner.

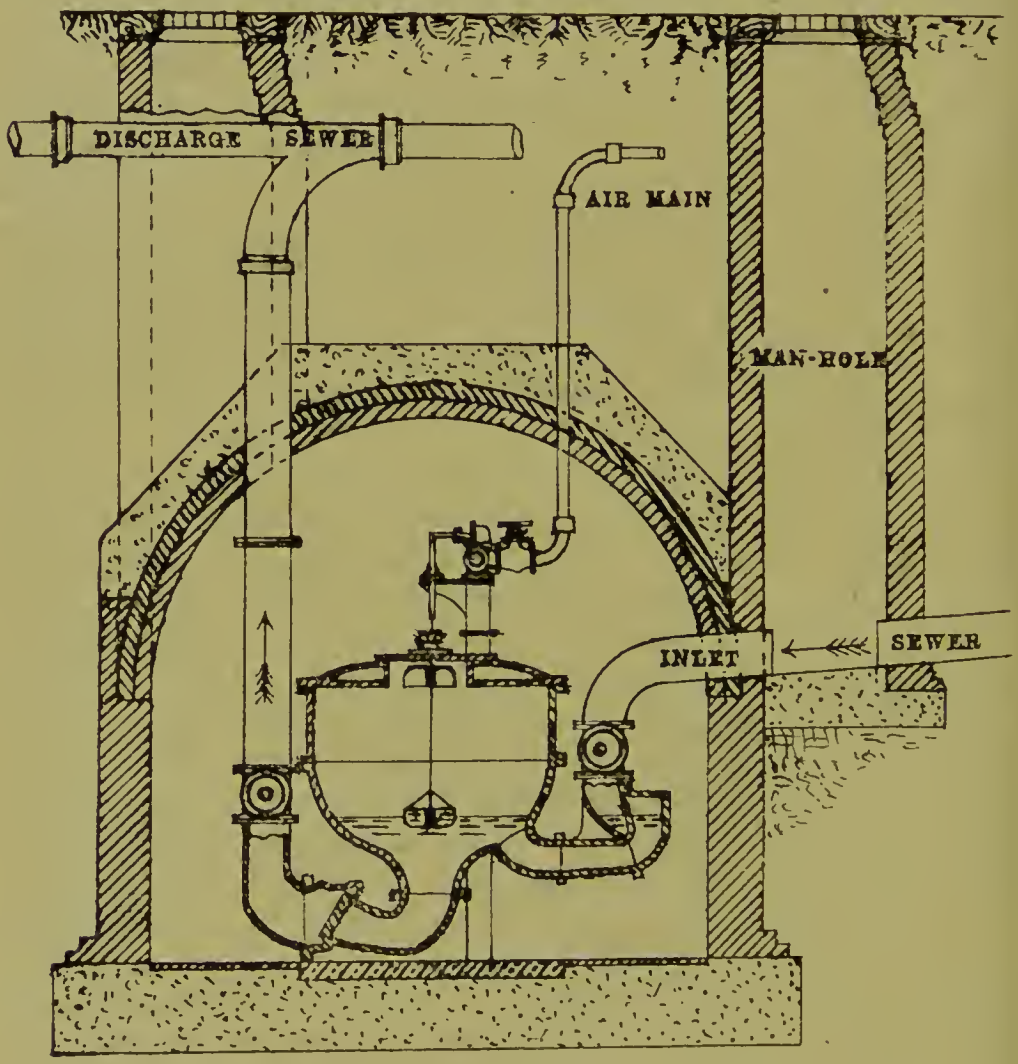
One of the main objects of the system is, of course, to comply with the condition of the necessary velocity by adopting such means as will allow surface gradients to be, to a large extent, disregarded. This is accomplished by using iron receptacles, called ejectors, for sewage, fixed in suitable positions so as to allow of sewers properly proportioned and graded being laid thereto. The ejectors are made of various shapes and sizes according to the amount of sewage they have to discharge, preference being given, however, to those having the lower portion of a hemispherical shape. Employment of ejectors enables the town to be divided into small and suitable districts according to local conditions of gradients, population, outfall, &c., each district being provided with an ejector station. The sewage from each district gravitates through the sewer or sewers belonging to that district (which sewers need be neither large nor of great length, nor at great depth, as the district may be made any size) until it falls through an inlet valve into an ejector and the sewage continues to flow until the ejector is almost full, when a valve is automatically opened. The opening of these valves admits compressed air, which, rushing in, forces out the contents of the ejector into an iron pipe or sewer laid close to the surface level. This pipe carries the sewage either to an outfall, or to another ejector, should circumstances require further elevation of the sewage.

The air which works the ejectors is compressed by suitable engines at central or other stations, and is distributed in small pipes, like gas pipes, to each ejector to which it is admitted only when the ejector is almost full. There is great advantage in having, as it were, these detached pumping stations, for there is greater economy in the less height the sewage has to be lifted than if it were all brought direct, and through long distances to a pumping station. The system allows the sewage to be carried in small pipes of short lengths and easy gradients; it does not allow of the accumulation of noxious gas, and it implies a quick flow of sewage.

Rangoon is the first city in India which has adopted the system. Bombay has adopted the system in a portion of the city (Colaba). Among other places where it is in operation are Eastbourne, Henley-on-Thames, Southampton (partly), and Warrington. It has also been successfully applied to the drainage of certain large buildings in London, the chief of these being the Houses of Parliament, the Royal Courts of Justice, the National Liberal Club, Winchester House, Old Broad Street, &c. The sewers of the Houses of Parliament

were laid down in 1839 by Sir Charles Barry and were altered in 1846. On the completion of the London main drainage works, they were found to be complete sewers of deposit, owing to the high level at which the sewage was always flowing in the main sewer into which the sewers of the Houses discharged. Matters became so bad that on one occasion in 1886 the House of Commons had to suspend its sitting, and a committee was appointed, Sir Henry Roscoe being chairman, to report thereon; the result was the adoption of the Shone Hydro-Pneumatic system which is said to have given Parliament entire satisfaction.

A sectional elevation of an ejector station is shown in the following diagram :—



Summary of advantages.—The advantages of the system may be summed up as follow :—

(1) Good gradients for the sewers are always obtainable.

(2) Deep excavations are avoided.
(3) Large-sized sewers are avoided.
(4) The length of the sewers is decreased.
(5) The sewage is kept constantly in motion.
(6) The outfall may be at any desired level.

Hydraulic system.—Somewhat similar economies can be secured by the introduction of what are known as hydraulic pumps worked at stations in each of several small areas of a town. These pumps are driven by the pressure of water sent through hydraulic mains from a central pumping station exactly on the principle of the Shone system; in the latter system, however, air is the motive power, while in the former the water raised for pumping has to be obtained and then got rid of.

SEWAGE PUMPING.

For raising sewage in small quantities, viz., from the sewer outfalls of small villages if a small amount of storage can be provided, the lifting may be done by picottahs, chain pumps, bullock lifts, &c., but where the flow is considerable, steam pumping machinery is necessary. Even with steam machinery, an amount of storage is necessary; by its intervention, pumping at nights may be saved, and this is desirable in India, because drivers cannot be trusted to work satisfactorily at night with reduced quantities of sewage flowing to the pumps which can be stored to a great extent in the sewers, and if the sewage is being pumped on to land, it is better it should reach the land and be distributed during the day. Of course storage room can, as an alternative, be provided at the sewage farm, but this will not do away with the necessity for pumping at nights, when, if pumping is not continued regularly, deposit takes place in the sewers. When storage room is provided at a pumping station, the maximum surface level of the sewage should be below the sewer inverts. Sometimes the outfall sewer itself is enlarged to store sewage, but this plan cannot be recommended.

Sewage pumps.—A class of pumps suitable for lifting sewage is the centrifugal, and these are recommended where the lift is moderate. Pumps of the Worthington class are also often adopted in India. They are of very similar design to those used for water-supply.* It is not advisable to use sewage for condensing purposes in surface condensers; the tubes get very quickly blocked with matters in the sewage. The power required from engines and pumps must be

* *Vide* page 328.

calculated in reference to the maximum flow of sewage, and where rainfall is admitted to any extent into the sewers, provision must be for a large reserve of machinery.

SEWAGE DISPOSAL.

Methods of disposal.—The following are the various methods adopted for the disposal of sewage :—

(1) Discharge into running water.
(2) Discharge into the sea.
(3) Subsidence in tanks.
(4) Precipitation of solids by chemical means.
(5) Filtration through charcoal, iron, sand, gravel, &c.
(6) Application to land.

The advanced state of sanitary science shews that No. 1 is objectionable, unless the volume of the river be very large in proportion to the quantity of sewage, or the fall of the stream very considerable and velocity great, so that by æration and oxidation the sewage matters quickly disappear.

Only in few places can No. 2 be adopted, and the sewage is apt to be carried up and down the coast or else swept on shore again by the direction of the currents or action of the tides.

Under method No. 3 the sewage is stored in tanks until the solids subside and the liquids are then run off. It can be done only on a small scale and is even then unsatisfactory in its results.

The object of precipitation (No. 4) is to purify the sewage so that it is fit for admission into a river. The solids are thrown down with chemicals; the solids may be dried and pressed into cakes and then applied to land, used for making cement, or mixed with earth and ashes and sold for manure. Among the different substances used for precipitation are salts of lime, magnesium, carbon, iron, zinc, &c. The very existence of so many processes and patents shews that none of them are quite satisfactory. The objections are these: (1) the water is not really purified though apparently so, (2) the precipitate is worth little or nothing, (3) the process is expensive and gives no return.

Filtration (No. 5) through charcoal or iron has not given satisfactory results, but filtration through sand has been found efficient as shown by the following record of experiments made by the Massachusett's Board of Health with the sewage from

the City of Lawrence on the Merrimac river. The sewage was the ordinary city sewage. The total * solids amounted to from 3·5 to 12·5 per 1,000.

Several tanks for filtration were tried, but the one, which gave the most satisfactory results, was a tank (No. 1) 17′ 4″ × 16′ 8″ × 6′ 0″. The drain in the tank was 15 feet long of horse shoe section, 2 inches square in area with the open side down laid on blocks 6 inches apart and half an inch above the floor. The floor was covered with coarse gravel stones 1″ × 2″ in diameter; above this layers of gravel decreasing layer by layer to $\frac{1}{8}$″ × $\frac{1}{8}$″; on the top of this was placed coarse mortar sand 3$\frac{1}{2}$ inches thick at centre of tank. Over the layers thus prepared there were 5 feet of very coarse sand. It was found that nitrification of the sewage was the work of an organism or ferment, which acting on the sewage in the presence of atmospheric air was able to oxidise it. The presence of air was found absolutely necessary and this could be obtained only by intermittent filtration. The nitrification of the sewage did not occur until the filter had been some time at work, the nitrifying organisms requiring some time to multiply to sufficiently deal with all sewage flowing through the filter. A filter must be very open grained at the top if nitrification is to be effected.

The results of two years' experiment with the above tank, 76 per cent. of whose particles had a diameter ·02 to ·09 of an inch, showed that, at the rate of 48,000 gallons per acre per day, 99 per cent. of the organic matter in the sewage was destroyed and the bacteria found in the effluent numbered less than one-tenth of the number in the raw sewage. Larger quantities of sewage up to 180,000 gallons per acre per day were also filtered and 97 per cent. of bacteria removed, but this rate could not be efficiently maintained.

Filtration, a biological process.—The experiments prove that filtration is not mere straining, but that organic matter in the sewage is burnt up and destroyed by the action of an organism, which experiments in America have now isolated for the first time. The organism will not grow in gelatine culture. The organism requires a supply of air and hence intermittent filtration is necessary; even when gravel, the size of pigeon eggs, was used the purification was very perfect.

Application of sewage to land desirable.—The results of practical experience pronounce emphatically in favour

* The average solids in London sewage amount to four parts per 1,000.

of applying sewage directly to land and this entirely agrees with the dictates of reason. Nature's cycle is, that the animal world is supported by the vegetable and the vegetable in turn by the animal, each finds its sustenance in the other. Vegetation feeds on decomposed animal and vegetable matter, converting substances noxious to the life of animals into healthy vegetation when dissolved by water and taken up by the rootlets of plants. The same vegetation is, in its turn, the food of animal life, which in process of its growth throws off the refuse to feed vegetation again. Nature thus puts into our hands an absolute solution of the problem of dealing with our refuse.

Of the organic matter to be removed from our houses that portion of animal origin is destructive to the healthy life of animals, but is necessary to plant life, and through plants to the animals which feed on them; and to bring back these elements which were poisonous to animal life in the form in which they were thrown from it, they must undergo that complete transformation, which, passing into vegetable life, involves before they become again fit for animal food.

Action of air on sewage.—The cleansing of sewage is therefore essentially a chemical and biological one, because when sewage is exposed to the action of air, the organic matter becomes oxidised and changed into harmless substances.

Stagnating sewage, a nuisance.—Sewage should be kept moving and should be conveyed to the earth as quickly as possible. It is stagnation of sewage which causes nuisance and which prevents sewage being used profitably.

Action of the earth on sewage and effects.—The pores of the earth are at all times filled with either air or water; when air is expelled the other takes its place. That part of the organic matter of sewage, which is so far decayed as to be readily assimilated by vegetation, is at once removed in that way, another portion is stored in the earth awaiting further decay, any surplus is carried down and if the earth is porous enough or if there are deep laid drains the air follows it and changes the decaying organic matter into harmless substances by a process of oxidation.

The above theory has lately been modified, and it is said that experiments show that nitrification in sewage and soils is the result of the action of an organised ferment which occurs abundantly in soils and impure waters; that nitrification is strictly limited to the range of temperature within which the vital activity of living ferments is confined; this

nitrification proceeds with extreme slowness near the freezing point, increases to about 99° Fahr. and stops at 135° Fahr. The Health Officer in Madras states that in the cold weather the temperature of the soil is 80° to 100° Fahr.; in the hot weather this will be higher, and less nitrification will therefore be taking place near the surface during that period; a greater depth of porous or specially prepared soil is therefore necessary than in more temperate climates.

From the results of experiments, it appears that in a clay soil the nitrifying organism is usually confined to about 18 inches of the top soil and is most abundant in the first 6 inches. In sandy and porous soils and in soils broken up by the passage of worms or roots of plants, the organism is at a much lower level than this and has been found to exist in porous soils at from 3 to 4 feet below the surface.

Air is necessary for these organisms to discharge their functions; when sewage is allowed to flow on to land, it displaces the air in the pores of the land and drains down through the earth; therefore, as will be deduced from the foregoing remarks, sewage must not be continuously applied to the land, or the necessary supply of air will cease and thus prevent the sewage undergoing those processes which render it innocuous; irrigation must, therefore, be arrested, and if sewage is applied for 4 or 5 hours, then the land will require 12 to 18 hours for renewal with the fresh air which is a necessity.

Preparation of land for sewage farming.—Land may be prepared for the purification of sewage in two ways, viz., for broad irrigation or intermittent filtration.

Broad irrigation.—When broad irrigation is used, the land must be fairly even, but with a slight slope, so that the sewage may travel slowly over the land and admit of the surface being equally wetted throughout and so that the surface may be dried subsequently to the application of the sewage.

Intermittent filtration.—When intermittent filtration is the method by which purification is to be effected, the land is laid out in beds and the sewage applied to each bed passes vertically downwards through a pervious stratum in a more or less purified condition and escapes by means of drains or otherwise.

Laying out of land for sewage irrigation or filtration requires considerable care and attention. When the subsoil is sand, gravel or other porous material, the subsoil

water finds an easy outlet with or without artificial aid into streams, water-courses, &c. Where clay is the soil, its treatment is difficult. If drains are laid in the clay, when the land is dried for cutting the crops, cracking will result and the sewage will pass to the drains without being filtered at all if there is only a slight depth of soil over the clay. Clay, therefore, cannot be drained for sewage farming, and as sewage should not be put on to non-porous soil without subsoil drains, it is a soil that should be avoided unless a thick coating of porous soil is previously spread over it.

The depth, at which drains should be laid, is evidently determined, to a great extent, by the results of experiments as to the depth at which nitrification positively ceases; this, as previously stated, is at a depth of 3 to 4 feet, and in this view it is unnecessary to prepare intermittent filtration beds as deep as was formerly thought necessary, viz., 6 feet. Dr. Frankland has stated that, whereas in the Rivers Pollution Report, he recommended that depth, he had now reason to believe that 2 feet would be equally effective. These facts are substantiated by the rapid purification which sewage undergoes when applied to the soil immediately below the surface as in sub-surface irrigation. Koch says that, in the soils he examined, bacteria were nearly absent at a depth of one metre; why this should be so may be deduced from the explanation of the nature of the filtering process in regard to water already explained.

Broad irrigation is a system obtaining in England to a large extent, the surface being chiefly depended upon for purification. It would seem, at first sight, a form suitable for application in India, but sanitarians are usually averse to any system which does not include sub-soil drainage; when, however, an area at a distance from habitations under rice cultivation with a porous soil is available, the system is one which may be applied, ditches and intercepting drains being provided, and all wells on the sewaged area or within a radius likely to be affected, being closed.

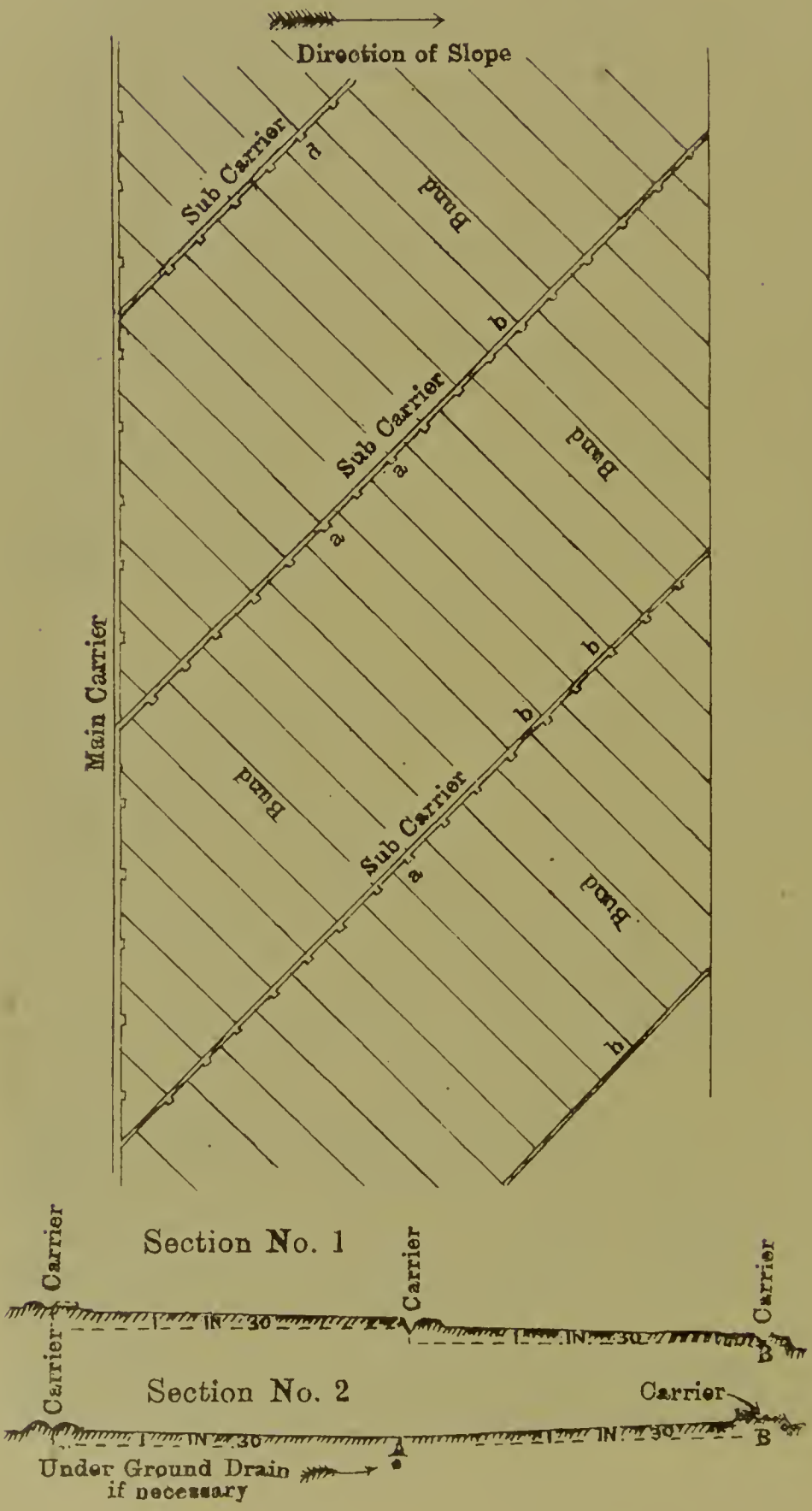
Intermittent filtration.—For intermittent filtration beds must be formed, so that sewage may be distributed first to one bed and then to another, to allow requisite intervals of rest. For broad filtration also, where the land has a slope greater than is suitable for the proper rate of flow of sewage under irrigation conditions, it must be formed into beds or small fields. This need hardly be explained, for in India paddy lands are seen under a variety of conditions, situations, slopes, &c.; the size of the beds will depend on the

nature and variety of the crops, and more particularly on the slope and contour of the ground. They should be such that the sewage can be easily, quickly and evenly distributed over each portion of the bed; too much slope for a bed is as bad as too little; therefore in order to save expense, where the original surface is too steep in its natural state, short beds are advisable. Beds may be laid out as shown in the diagram on page 486, which pre-supposes the conditions that the slope, at right angles to the main carrier, is excessive. The beds in this case must be given a proper slope by excavating the end (*a*) and raising the end (*b*). The smaller the beds are, the less will be the cost of excavation to obtain a proper slope. The slope may be as high as 1 in 30, and even this, if the soil is very porous, may be insufficient to distribute the sewage evenly. It is, therefore, necessary to limit the length of a bed, and in some soils a 50 feet length for a 1 in 30 slope is a maximum. The determination of the size and length of beds is a matter of experience and convenience in respect to the natural features of the area to be irrigated. Under the broad irrigation system, the land is completely submerged and a constant depth maintained by bunds round each separate area under culture.

Distribution of sewage.—The carriers or drains conveying the sewage to the land should be of the most simple character possible; the main carriers may be open brick-lined or concreted channels. Very often earthen embankments with large open semi-oval shaped channels made of stoneware will suffice.* The sub-carriers may be made of similar but smaller tiles laid on earth banks, the smallest-sized carriers may be simple furrows or trenches cut in the ground. Branches and T pipes will be required on the main and secondary carriers; the flow of the sewage out of the larger carriers may be regulated by small masonry sluices with wooden doors; outlets from other carriers may be closed simply by clods of earth. It is desirable to have on a farm, if possible, considerable storage capacity for sewage; in the first place sewage is best applied during the day only and, in the second place, when rainfall occurs excess sewage must be used up somehow, and if it cannot be pumped, it must be stored. If the sewage farm area is of an undulating character, on elevations divided from one another

* Dr. Nield Cook, Health Officer of Madras' experience is that even for the main carriers simple earth conduits such as are used in our Indian irrigation channels are all that is required.

SEWAGE FARMS



by small valleys, it is advantageous to arrange that each separate area should be commanded by a small tank into which the sewage can be pumped direct from where it is raised; such tanks can be discharged by means of a syphon action as often as required. It is desirable to distribute sewage in this way, as considerable velocity and better distribution can be ensured. Tanks for storage purposes or for receiving storm waters should be placed at the higher points of each district or on ridges within the farm area. Those at Berlin are made with earth banks and so as to be 3 feet deep. They are from 5 to 22 acres in extent and form storage tanks when the sewage cannot be distributed owing to frost.

Area required for intermittent filtration.—The cleansing power of a soil is dependent more on its physical than its chemical conditions. Certain soils will effectively purify about 10 gallons per cubic yard of soil per day, others only 4 gallons. The former quantity is equivalent to cleansing nearly 100,000 gallons per acre per diem, the latter to 40,000 if drains are 6 feet deep. The former quantity represents the discharge from a population of 6,000 people at 15 gallons per head, the latter of 2,666 people. If the purifying action of the soil does not go deeper than 3 feet, then the latter figures will be 3,000 and 1,333.

It was at one time estimated in England that the yield of a population of 2,000 persons could be disposed of on an acre; this was soon found to be too high and 1,000 persons in England is considered the maximum: this latter quantity even is not accepted without doubt of its correctness. It is evidently incorrect to consider the population in reference to the acreage; what ought to be considered in all cases is the quantity of sewage and its composition. Now it is evident that for a water closet town a greater area will be required than for a town which has the dry-earth system, and a town yielding 30 gallons per head will require double the area of one with an equal population yielding only 15 gallons per head. In England 1,000 persons would yield 30 to 40 gallons per head or, say, 30,000 to 40,000 gallons, in India only 15 to 20 gallons per head or, say, 15,000 to 20,000 gallons. If then an acre is required in England for 1,000 persons, an acre in India (especially as only very few towns are water closet towns) ought to be sufficient for 2,000 persons, and with very suitable well-drained soil 3,000 persons (45,000 to 60,000 gallons) per acre would not be excessive.

The following gives particulars of the areas and amounts of sewage applied to certain English sewage farms on which the intermittent system is in use :—

Names of places.	—	Gallons per diem draining to farm.	Acreage of farm under filtration.	Acres per each 30,000 gallons per diem or say 1,000 people.
Dewsbury	Intermittent.	900,000	50 for filtration, 12 for irrigation.	2·0
Hitchin		300,000	19 acres.	1·9
Merton		1,500,000	28 do.	0·56
Swanwick		120,000	15 do.	3·75

The foregoing table shows great variation due, no doubt, to the varied porosity of the different soils.

Area required for broad irrigation.—Under broad irrigation the number of gallons which can be discharged on the soil is much less than under the system of intermittent downward filtration; it is probable that for India 7,500 gallons per acre per diem would not be excessive. An acre would, in such case, be sufficient for a population of 500 people yielding 15 gallons per head or 2·0 acres per 1,000.

The following particulars among others regarding English sewage farms were collected by the Borough Surveyor of Leicester :—

Town or district.	Population.	Acreage of farm.	Area to which sewage is applied.	Character of subsoil.	Quantity of sewage dealt with in 24 hours.	Area of farm under intermittent filtration.	Remarks as to previous treatment of sewage beforehand.
			ACRES.		GALS.		
Aldershoot ...	12,000, 10,000 to farm.	8	8	Loamy sand	389,000	None ...	Sewage treated with sulphate of alumina and lime previously.
Bedford	25,400	223	130	Loam 3 feet, gravel under.	1,000,000	None ...	Sewage applied raw.
Burton-on-Trent ...	46,500	556	430	Gravel	5,000,000	130 acres ...	Do. do.
Doncaster	23,625	278	...	Light gravelly subsoil.	500,000 to 600,000	Practically none.	Do. do.
Oxford	50,000	370	335	Sand subsoil but part clay.	1,300,000	32 acres ...	Do. do.
Rugby	11,000	70	70	Loamy to 4 feet below gravel.	250,000	None ...	Do. do.
Warwick	12,000	165 120	165 100	Clay gravel	750,000	Do. ...	Applied raw after passing settling tanks.
Wimbledon ...	25,000	73	73	Clay except 16 acres gravel.	600,000	Do. ...	One-sixth applied raw after rough filtration; remainder treated chemically.
Wrexham	12,000	84	42	Drift gravel ...	400,000	About 2 acres under drained.	Applied raw to land after sludge was settled.

The following shows the number of gallons to each acre under cultivation and number of acres per 1,000 people taking the yield as 30,000 and 20,000 gallons respectively, or at 30 and 20 gallons per head :—

Town or district.	Areas.	Gallons per diem.	Gallons per diem per acre.	Population at 30 gallons per head.	Population at 20 gallons per head.	Acres per 1,000 people.		Persons per acre.	
						30 gallons per head.	20 gallons per head.	30 gallons per head.	20 gallons per head.
	ACRES.					ACRES.	ACRES.		
Aldershoot ...	8	389,000	48,625	12,966	19,450	0·62	0·42	1,620	2,431
Bedford	130	1,000,000	7,692	33,333	50,000	4·0	2·6	256	385
Burton-on-Trent ...	430	5,000,000	11,630	166,666	250,000	2·5	1·7	388	582
Doncaster ...	278	500,000	1,800	16,666	25,000	16·7	11·1	60	90
Oxford	335	1,300,000	4,000	43,333	65,000	7·7	5·1	130	194
Rugby	70	250,000	3,570	8,333	12,500	8·4	5·6	119	178
Warwick ...	165 100	750,000	2,830	25,000	37,500	10·6	7·1	94	141
Wimbledon ...	73	600,000	8,220	20,000	30,000	3·6	2·4	274	411
Wrexham	42	400,000	9,520	13,333	20,000	3·2	2·1	317	475

The following table refers to the sewage farms which receive the sewage of the City of Berlin :—

Farm.	Acres treated for each 1,000,000 gallons daily sewage flow.	Persons per acre.
Osdorf	223	198
Gross Beeren	256	141
Falkenberg	303	165
Malchow	403	122
Average ...	268	156

These farms, originally formed without drains, have since been underdrained. The drains are of 2 inch tiles laid parallel to the surface joining master drains 3 inches to 6 inches in diameter. The drains are 16 to 33 feet apart ; the cost was £8–10–0 per acre drained.

Sewage filters.—Referring again to experiments made at Lawrence (Massachusetts), the results were as follow :—

Soil.	Number of gallons of sewage one acre is capable of purifying indefinitely.	Number of persons at 15 gallons per head.
Coarse sand	117,000	78,000
Coarse and fine sand and fine gravel.	42,600	2,840
River silt	134,000	790
3 feet 8 inches of sand and gravel, 10 inches yellow loam, 6 inches brown soil	8,880	592

During the 1893–94 session of the Institute of Civil Engineers, Mr. Sydney Lowcock read a paper in reference to

certain experiments he had made with sewage filters. The filters were composed of sand and broken stone to a total depth of 3 feet 1½ inches; air was blown into a central layer of stone in the filter with a pressure of about 4·5 inches of water. The quantity of sewage applied, when the most satisfactory results were obtained, was 263,780 gallons per acre per day; with a properly aërated filter, by increasing the depth of material, a greater degree of purification will be attained than by increasing the area, or more sewage can be put on the same area, with an increased depth. Sewage filters are very suitable for dealing with comparatively small amounts of sewage from hospitals, jails, schools, &c., or at places where suitable land for sewage irrigation cannot be obtained.

Sewage farming in India is yet in its infancy. Madras is the only town where it has developed to any extent. The original farms in Madras were placed on ground convenient to existing outfalls without much thought as to porosity of soil, drainage, &c. Some of the sites were old rubbish depôts. The collection of rubbish had replaced low swamps, so that the under soil was no doubt damp and often water-logged, though the made-soil above was porous to a considerable extent. The cultivation of the surface of such depôts is no doubt a sanitary measure so far as they are concerned, but they were not the best places for sewage farms. Some of the farms have extended far beyond the limits of the original depôt. The largest farm in Madras is the Black Town farm, formed by the author in connection with the Black Town drainage works; it was formed on a plain sloping towards the sea along which it extends; the soil is sand, extremely porous and no under-draining was attempted. The farms are worked on the intermittent system or a modification of that system.

The following information, extracted from a paper of Dr. Nield Cook, Health Officer of Madras, gives information regarding the Madras farms:—

"Dr. Cook states that, in writing his paper, his object is to show that the adverse conditions, which prevent the general adoption of this method of sewage disposal in England, are, for the most part, absent in India, and that a trial extending over a quarter of a century in Madras proves that an unlimited amount of sewage can be disposed of in this way in accordance with the best hygienic principles, and further that the farm produce finds a ready market. The first

experiment in sewage farming was the cultivation of an area reclaimed by rubbish, the area had been a swamp with a clay subsoil; this farm was at first a failure owing to water logging. The next experiment was at Kistnampett, where part of the area had been reclaimed by the disposal of rubbish and part was pure sea sand. Owing to the porosity of the subsoil, the farm is a success and as much as 69 tons of grass per acre have been raised. Since then a number of farms have been started including the Black Town farm. Dr. Cook considers this farm to be a fair model for an Indian Sewage farm and describes it in detail as follows:—

"The sewage passes from the outfall channel through culverts with sluices into the main carriers. These are banks of earth with a channel scooped out on the top. They run in parallel lines about 432 feet apart, giving off at right angles, the secondary or distributing carriers which are similar, but somewhat smaller. The interval between the distributing carriers is 114 feet, and it is divided into two by a small bund, which runs through the beds half way between them. This may be called the central bund. The beds slope down to it from the distributing carriers. It is absent in some of the farms, but it is thought it is a good thing to have it, as the grass may rot at the lowest part of the slope through the water standing there longest. It percolates through the bund, and so this is avoided. There are further bunds at intervals of 6 to 8 feet running from near the distributing carriers down to the central bund. These are small and not more than 4 to 6 inches in height. They conduce to the equal distribution of the sewage over the grass. The junction of a distributing carrier with a main is made with a stoneware drain pipe of about 6 inches diameter. Grass grows freely over the bunds and over the carriers to the very edge of the channels, which become coated with a black sludge, which hinders the sewage from sinking in, though it allows enough percolation to keep the grass growing freely over them. Large drain tiles have been laid in some of the carriers, but they soon get displaced and serve no good purpose. The gradient of the carriers should be sufficient to ensure a fairly rapid flow without causing a scour. Where the amount of sewage to be disposed of is small, the beds should be made somewhat smaller than the measurements given in order to get even distribution. The slope from the distributing carrier to the central bund is about 1 in 30.

"The system of irrigation, which has been found to answer best, is to flood the beds heavily every three or four days, though it can be done oftener without any ill-effect. The

method employed is to open the sluice in the outfall channel and let the sewage run into a main carrier. The drain pipes leading to the distributors to be used are left open; those which are not to be used are closed with earth and grass. If only the first part of a main carrier is required, it can be bunded across at the required distance with earth. The same can be done with a distributor, which is then breached behind the barrier, and the sewage pours out and runs down the space between the distributor and the ends of the bunds that divide up the beds, and turns off between these bunds to run down the beds to the central bund. The men in charge of the farms say that they put on about 4 inches at a time, but the amount must be much larger, as a good deal of sewage sinks in before it begins to lie on the surface. This method of intermittent irrigation economises the labour on a large farm, as only a third or a quarter of it has to be attended to every day. It also gives plenty of time for air to be drawn into the interstices of the soil and provide the oxygen which is necessary both for nitrification and the formation of tissue. Most cultivators irrigate equally all the time a crop is growing, but one of great experience states that the younger the grass the more sewage it will take. The grass should not be irrigated for two or three days before it is cut. This allows it to harden, and though it does not weigh quite so much, its quality is better and it does not wither so quickly. After the grass is cut, which is done in Madras with a sickle with a saw edge, the teeth being set the contrary way to an English saw, the ground should lie fallow for the best part of a week. The careful farmer will then take the opportunity of forking it and loosening the roots, though in some farms this is not done more than once a year. It favours the development of young roots to replace the old ones, and so preserves a healthy and vigorous growth. The beds should also be weeded. If this is done regularly, it entails very little labour, but if it is neglected, there may be some difficulty experienced. The grass is generally cut rather before it reaches maturity. The farm contractor reckons to cut a crop every 45 days, which gives eight crops a year. In the Municipal parks, where sewage irrigation is carried on, so many are not obtained. The method of irrigation by blocking the channels with earth and breaching them is primitive, but it suits the native cultivator, who is very skilful with it, and it has been found to answer the purpose, so no attempt has been made to supersede it and introduce iron or wooden stoppers.

"Some of the three million gallons of sewage daily pumped at the Ráyapuram station is drawn off to irrigate the

Robinson Park, the remainder goes to the Black Town farms. Adding together the area of the park, the farm and of certain private lands adjoining the farm, which are irrigated by the contractor, the total is 40 acres approximately.* This gives a daily average of 75,000 gallons per acre. The experience at the Berlin farms is that not more than 2,000 to 3,000 gallons† of daily sewage should be allotted per acre, so that the land may have the necessary periods of rest. At the Bedford farm in England, about 5,200 gallons per acre are pumped daily, and at the Beddington farm about 6,600 gallons, which is the largest amount known of, outside Madras.‡ Yet the Madras contractor, who is getting twelve times as much sewage per acre as any European farm would stand, recently petitioned to have sewage irrigation stopped in the Robinson Park on the ground that he was not getting enough. This is a remarkable testimony to the porosity of the soil and the copious evaporation that takes place under the influence of the Indian sun. The sewage which is used to irrigate the farm does not form a definite effluent, but, on careful examination, tiny rivulets are found trickling down from near the bottom of the wall of sand in which the farm ends, where it drops down to join the sea-shore. The amount is so small that it was a long time before it was noticed.

"As regards the crops that do best, though it has been found that nearly everything will grow under sewage irrigation, later experience has confirmed the verdict of the early experimenters in Madras, that harriali grass (*Cynodon dactylon*, Hind. *Dhoob*) is by far the most satisfactory. It has the advantage of being indigenous; for English and French experience has shown that the particular crop, whatever it may be, that suits the neighbourhood seems to flourish under sewage. It is, moreover, a voracious feeder and is not easily killed by excess of sewage. In the wild state in places where there is not much moisture, it creeps for the most part below the surface of the ground. Native ponies may be seen scraping the surface of the ground with their hoofs and blowing away the dust to get at it, and will graze where there is not a blade of green grass to be seen. But, when abundantly irrigated, it shoots up to a height of 2 feet or more and yields most luxuriant crops. A good farm yields about 45 tons of

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* These figures do not agree with the figures given on page 501 where the latest figures will be found.

† The latest returns show that from 2,500 to 4,500 gallons per acre are used in the Berlin farms.

‡ This statement is not quite correct, see statistics already given.

green grass per acre, which dries down to about 15 tons of hay. This compares very favourably with the Berlin farms, which yield 25 tons of grass or 5 tons of hay. From this it would appear that the grass grown in Madras contains less water than that grown in Germany. The English sewage farms yield about the same amount of hay as the German ones. This is about double the yield from English meadow land. So where 1 ton of hay is got from meadow land, 2 tons are obtained from European sewage farms and 6 tons from Madras sewage farms. This enormous difference may be partly attributed to the season of growth being continuous in India, whereas in Europe it is limited to the summer months, and partly to the fact that a high temperature in a soil or water up to 99° Fahr. increases the activity of nitrification and consequently the vegetable growth. The hay from the Madras farms is mostly sold to the Commissariat at Rs. 45 a ton. This gives an average money yield of Rs. 675, or about £37 sterling per acre (taking Rs. 18 to the pound) against £18 per acre, which is reported to be the average price of Italian rye grass grown on the Bedford sewage farm. When the differences in the cost of land and labour in the two countries are taken into account, it is easily seen how it comes to pass that sewage farming is so much more profitable in India than in England, for there is double the produce at less than probably a quarter of the outlay. Besides the supply of hay to the Commissariat, there is a fair market for grass and hay among horse owners in the city, especially during the hot weather when grass is scarce.

"With regard to the quality of sewage farm hay as forage, Veterinary-Major W. Gladstone, A.V.D., the officer in charge of the horses of H.E. the Governor's Body Guard and the Royal Artillery at St. Thomas' Mount, writes:—

"'Since hay from the sewage farms has been used at the Mount, there has not been a single case of anthrax until this year, when on inquiry I found that one of the Majors was using grass-cutters' grass. This was stopped and since then we have not had a case. The same in the Body Guard. I strongly recommend hay from the sewage farms, as diseased cattle are not allowed to stray over the land, and it is by far the best forage you can get in Madras.' Veterinary-Colonel I. S. Shaw says, 'wherever dry hay has been used, anthrax has not been known, and certainly I have not seen a case. In Belgaum in 1878, we had anthrax, and as soon as the grass-cutters were discharged, it ceased and has not recurred since. The same in Bangalore, except when they are compelled to use green grass, as in camps of exercise, &c. So

I believe the drying process and keeping diseased cattle off the land had a great deal to do with this immunity.'

"Harriali grass grows better from roots than from seed. The roots should be planted in rows about 6 inches apart. It spreads quickly and in about two months a light crop can be cut. If it is planted in a soil recently made by the deposit of rubbish, the irrigation should be somewhat excessive, daily will not be too often. Otherwise the heat due to fermentation may kill the grass. Beds, both of sand and of made soil, planted more than twenty years ago, are still yielding good crops, though they have never been ploughed up or replanted. If a bed sinks in any part a few cart loads of rubbish will restore the level. If caterpillars appear, as they occasionally do about the end of the rainy season, a little freshly-slaked lime will quickly put an end to them, failing which, ashes are as good as anything.

"Complaints of nuisance have been made against some of the Madras farms as against most sewage farms in other places. There is an ammoniacal smell from the sewage wells and main carriers at times, but apart from this the air over the farms themselves seems perfectly fresh and wholesome. No one with his eyes bandaged could perceive by the sense of smell that he was walking over a sewage farm.

"With regard to underdrainage, its objects are to prevent the soil from becoming water-logged, which ruins the crops and prevents the proper exercise of its purifying action on sewage, and to enable a larger quantity of liquid to be disposed of. It has never been successfully employed in Indian agricultural operations. In a trial made at the Saidapet experimental farm, it was found that its efficiency was destroyed through the pipes getting blocked by white ants, &c. It is quite unnecessary in a highly permeable soil that permits free percolation. In the Berlin farms it was not adopted at first, but was subsequently resorted to when the soil got water-logged, 2-inch pipes being laid 16 to 33 feet apart at an average depth of 3 to 4 feet. In most of the Madras farms there is no water to be found above a depth of 5 or 6 feet. There is no impervious stratum under them for a considerable distance down, D'Mellow's Road Farm being an exception, as it has an impervious stratum and is only slightly raised. In England and Germany it is found that less than half the sewage used for irrigation flows away as an effluent. In India the proportion must be very much less, as evaporation and transpiration are enormously increased under the influence of the tropical heat.

"This enables large volumes of sewage to be used for irrigation without under-draining and without appreciably raising the level of the subsoil water. What little effluent percolates through the farms may safely be allowed to join the subsoil water without any fear of polluting it or in any way endangering the public health; already good reason has been shown for believing that there is not very much of it, that the water level is not appreciably raised and that the crops are healthy and vigorous. Hence, so far as can be seen, no reason exists for under-drainage, which would, moreover, entail great difficulties and expense; for the ground is so level that the effluent would not run off, so that it would have to be pumped, and there would be nowhere for it to go to unless it were thrown on to the beds again, and so be sent round and round in a vicious circle.

"Under the arrangement with the sewage farm contractor, the Municipal Commissioners undertake to pay the rent, establishment and labour. The contractor must keep in repair the sewers, drains, cisterns, channel-pipes and other things connected with the delivery of sewage in or on the farms. He must dispose of as much sewage on the land as the Commissioners deliver. He must cultivate and manage the farms in the most approved manner and keep them in a clean condition, free from weeds, &c. He must allow free access to the farms to the officers and servants of the Municipality, in order that they may see in what state the farms are kept, and whether any part is in need of repair, and, if so, to give notice to the lessee, who must execute the repairs within fifteen days. The contractor has the right of constructing new wells, cisterns, &c., if he first obtains consent for the proposed work. The Commissioners agree not to stop the delivery of sewage at any one time for a longer period than five days. The contractor is allowed to cultivate or irrigate with sewage other land than Municipal land with the consent of the President, and pays to the Commissioners Rs. 250 per cawnie (1 cawnie=1·322 acres) per annum for lands so cultivated. The contractor has to cultivate and irrigate any other land acquired, rented or handed over to the Municipality and pays the Commissioners Rs. 300 per cawnie per annum for lands so cultivated.

"The contract system, which was introduced in 1888, has been found to be more profitable than working the farms departmentally. The usual objection to it is that a contractor has an eye only to profit, and will not use all the sewage on the farms for fear of injuring his crops. No trouble has been experienced from this cause in Madras

partly through the voracity of harriali and partly through the well-known prodigality of the Indian cultivator in the matter of irrigation.

"The farms are put up to public auction triennially. At the first sale in 1888, Rs. 7,250 per annum, or Rs. 21,750 for the whole period, was the highest bid. On this, if the cost of pumping on the farms be included, there was a loss on the three years as shown below :—

Income.

	Rs.	A.	P.
Rent of farms..	21,750	0	0
Loss	19,239	11	6
Total ..	40,989	11	6

Expenditure.

	Rs.	A.	P.
Establishment.	1,920	1	9
Overtime ..	153	10	8
Fitters' staff ..	721	1	3
Labour (including pumping) ..	35,414	5	10
Rent of sewage farms ..	2,780	8	0
Total ..	40,989	11	6

"This shows a loss of Rs. 19,239-11-6 or rather more than Rs. 6,000 a year. In 1891 the better price of Rs. 15,600 per annum, or Rs. 46,800 for the three years, was obtained; on this an actual profit of Rs. 18,307 was realised, the expenditure having been somewhat reduced. In 1894 the farms were let for Rs. 19,000 per annum, or Rs. 57,000 for three years. The following is an estimate of the income and expenditure for the period :—

Income.

	Rs.	A.	P.
Rent of farms.	57,000	0	0
Private land ..	14,850	0	0
Added land ($2\frac{1}{2}$ years) ..	5,312	0	0
Total .	77,162	0	0

Expenditure.

	Rs.	A.	P.
Maintenance, rent, &c. ..	30,630	0	0
Profit	46,532	0	0
Total ..	77,162	0	0

"The estimated profit for the period is thus seen to amount to Rs. 46,532.

"The conclusions drawn by Dr. Cook from the evidence adduced are as follow :—

"1. Barren land can be acquired at a moderate cost in the vicinity of most Indian towns.

"2. No matter how barren the land is, if it is permeable, it can be utilized for the formation of sewage farms.

"3. Sewage farms in India can be laid out at small cost, a maistry with a gang of coolies being able to do the grading of the beds and make the bunds and channels.

"4. Owing to growth being continuous, more crops can be raised in India than in Europe, and sewage can be more satisfactorily disposed of in very large quantities throughout the year.

"5. Owing to the temperature of the soil being particularly favourable to nitrification and growth in the presence of sufficient water, the crops are very heavy.

"6. Owing to the scarcity of good forage during a great part of the year, there is usually a good market for grass and hay.

"7. Owing to the exclusion of diseased cattle from the farms, the grass is not liable to infection with disease germs. The hay compares favourably as a food stuff with forage from other sources.

"8. Sewage farming can be carried on in the proximity of houses without affecting the health of the residents, though it is better to locate the farms at a distance from a town, as there may be some nuisance from the sewage wells and main carriers owing to the decomposition of the sewage before it reaches the farms.

"9. Owing to the porosity of the ground and the enormous volumes of water given off by evaporation and transpiration, under-draining is not generally necessary, though it may be in particular cases.

"10. Sewage, after passing through the ground, is sufficiently purified to be admitted in a river, or to join the subsoil water without causing pollution.

"11. The native cultivator is quite capable of laying out farms and carrying on sewage cultivation without close European supervision. He is an adept at irrigation processes, having inherited his aptitude and familiarized himself with the methods almost from the time of his birth.

"12. The system is suitable to parts of India where the ground is permeable and the rainfall is not excessive. It can be carried on profitably even where the flatness of the land necessitates the use of pumps, and should yield a much higher profit where the natural slope of the land permits them to be dispensed with." *

The following table is based on information furnished by Dr. Cook :—

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* The full report may be found in the Indian Medical Record of 16th April 1895.

Name of farm.	Acreage.	Amount of sewage delivered daily in gallons.	Number of persons contributing sewage.		Gallons delivered per acre.	Acres per 1,000 persons		Nature of crop.	Average number of days sewage is applied.	Number of days of non-application before cutting.	Number of cuttings per annum.	Weight of grass collected per annum.	Average weight cut from one acre per annum.	Actual value of crops per annum.	Rental received per annum.
			At 15 gallons per head.	At 25 gallons per head.		At 15 gallons per head.	At 25 gallons per head.								
Black Town * ...	53	2,500,000	166,666	100,000	47,170	0·32	0·53	Harriali grass.	10 days each crop.	One week.	About 7½ cuttings.	About 1,239 tons of green grass.	29½ tons.	About Rs. 20,500	Rs. 17,440.
D'Mellow's Road. Angalamman Coril Street.	16	200,000	13,333	8,000	12,500	1·2	2·0		three times each crop.						
Pudupet ...	4	20,000	2,666	1,600	10,000	1·5	2·5		...						
Egmore ...		10,000													
Dam's Road. ...		10,000													
Kistnampet. ...	14⅔	500,000	34,000	20,400	34,773	·43	·72		five times each crop.						
Royapett ...		10,000													

* Black Town Farm ... ... 17 acres.
Private Land ... ... 19½ „
Robinson Park ... ... 16½ „

53 acres.

Amount of sewage, possible of disposal on any area, limited.—Some of the conclusions drawn by Dr. Cook are such as are confirmed by the author's experience with these very farms, a large area of which he designed and formed. But there are others to which exception must be taken; for instance, the statement made at the beginning of the report that an unlimited amount of sewage can be disposed of, (unless Dr. Cook means that an unlimited amount of land is available), and if so, then the statement merely amounts to this, that a proper quantity should be applied to the available area. To apply more sewage than the land can properly purify year after year must end in entire cessation of nitrification and the whole of the land being made unsuitable for sewage farming. Besides this the fact that land is cheap and sewage farming productive shows that it is the most remunerative plan to limit the amount of sewage to what will produce good crops, and that in India it is not, as it is in England, advisable or desirable to limit the area and put on it as much sewage as the land can possibly take.

Under-draining.—Nor can the statement be accepted that under-draining in India is unnecessary. Where there are soils of porous sand, so porous that the sewage finds a ready outlet to the sea, it is possible that large amounts of sewage can be poured on to the land without under-draining being necessary, and this probably is the case with the Black Town farm; but where the soil is less porous and there is no under-draining, as is usually the case with farms on the broad irrigation principle on which in England the sewage of about 200 persons, 4,000 to 6,000 gallons (or as advised for India a maximum of 400 persons at 15 to 20 gallons daily= 6,000 to 8,000 gallons) is disposed of daily, these amounts cannot be exceeded with safety with a continued use of the farm. Where land is some distance from inhabited areas on which the people draw their water from the subsoil, sewage irrigation on the broad principle may be carried out in a manner similar to ordinary irrigation as practised in this country, but an unlimited amount of sewage can never be disposed of in any case; where sewage farms adjoin inhabited areas, under-drainage is almost an absolute necessity.

Admission of sewage to rivers and streams.—Nor can sewage from a sewage farm be generally admitted to a river without causing some pollution. It may be so thoroughly purified that the pollution is small in amount, the river may be of large volume and considerable velocity, and self-purification of the river may take place with con-

siderable speed, but unless all these conditions are present, pollution must occur; whether it will always be such as to have a marked effect on public health is another matter.

Leasing or letting farms inadvisable.—Notwithstanding Madras experience as to letting farms on contract, it is, as already stated, not a satisfactory measure. There is no guarantee that all the sewage is used especially if it can be diverted to an outlet without passing over the farm and any statements as to the quantity a contractor is said to use must be accepted with caution. Financial success again is no measure of the success of a sewage farm from a sanitarian's point of view; in fact very often it may be the reverse.

Madras, however, is the town in India, where the largest sewage farming operations have been undertaken; the conditions under which it is carried out, some of which are good and some bad, afford, if the latter be avoided, a practical guide for operations in other places and show at least, to some extent, what expenditure and results may be anticipated.

Crops.—The most suitable crops for sewage farming in India are harriali grass and paddy, because in regard to these there is no difficulty either in cultivation or sale. In Madras harriali grass is grown year after year and the yield is remarkably constant. But it is preferable to change the crops and an alternation of harriali grass and paddy might be beneficial. Other crops, such as turnips, carrots and onions, grow freely with sewage, so does sugar-cane. Near a town such crops as the latter are apt to be stolen and hence the recommendation of paddy and harriali grass. Casuarina trees and palm trees flourish well with sewage, but if sewage can be applied for only a specific and limited period, after sewage irrigation ceases, they do not flourish satisfactorily.

Farms should be in the hands of the Local Authority.—There is a fact, which must always be remembered, viz., that the reason for a sewage farm is not the growing of crops but the disposal of sewage. For this reason alone the author considers it desirable that the land should be in the hands of the local authority instead of being let out, for, undoubtedly the first thought of any occupant will be how best to make the farm pay, not how perfectly to dispose of the sewage. When a farm is let out there is little guarantee that no sewage will be passed to the outlet without previous filtration; during rainfall especially will there be every inducement to do so.

Sale of sewage.—Where, however, a sewage channel, drain or sewer passes through or near cultivable land, there is no objection to issue sewage on payment for a definite quantity. This should not be so much per acre of land irrigated, or sewage will be wasted and the land get water-logged; if sewage is charged for at so much per cubic yard, it is more likely to be used to the best advantage. Sewage farming of this description ought to be encouraged as far as possible and the ryots, near a town having sewage to dispose of, ought to be induced to apply it to their lands. There may, at first, be objection, but when a ryot finds out that he can obtain an unfailing supply for irrigation during all seasons of the year, his prejudices are very likely to vanish. He may not at first care to irrigate his rice fields, but if he will grow lucerne, guinea or other grass for his cattle, thence the transition is easy.

Sewage farming in India profitable.—No land is too poor for sewage farming; in Madras, as has been stated, grass now grows luxuriantly on lands which were sandy wastes impregnated with salt. Sewage farming in England is not, as a rule, productive; notwithstanding the primary purpose of a sewage farm, there is no doubt that sewage farming in India will pay. It is not correct (as Dr. Cook has done) to include in the farm accounts, as a portion of the expenditure on the farm, the whole expenses due to pumping and repairs to machinery; that expense would have to be met in any case in carrying the sewage to some outfall; if the sewage would in any case have to be lifted, then no pumping charges or only any exeess actually due to the farms should be placed against the farm revenue. The purchase of the land, the cost of preparing the area, the daily labour and expenses on the farm for distribution, cultivation, harvesting, &c., are fair charges which must be met; the revenue from very few farms formed in India should fail to exceed the amount of such expenditure and show a fair profit.

Sanitary aspects of sewage farming.—The supposed evils are the pollution of the subsoil water, of rivers, the atmosphere and the crops themselves. It may be said that, provided the area of land is sufficient and properly laid out, no nuisance need arise. The results of sanitary inquiry show that sewage farming is not detrimental to life or health. Dr. Alfred Carpenter, who devoted considerable time and attention to the question, at a meeting of the British Medical Association in 1888, submitted the following proposition:—

"1. That the application of the sewage of a water-closet town to land in close proximity to dwelling houses is not injurious to the health of the inhabitants of those houses provided the sewage be fresh; that it be applied in an intermittent manner, and the effluent be capable of rapid removal from the irrigated fields.

"2. The judicious application of sewage to soil of almost any kind, if it be mainly inorganic, will satisfactorily cleanse the effluent water and fit it for discharge into any ordinary stream, provided the area treated is not less than an acre for each 250 persons.

"3. That vegetable products grown upon fields irrigated by sewage are satisfactory and safe as articles of food for both animals and man.

"4. That sewage farms, if properly managed, do not set up either parasitic or epidemic disease among those working on the farm or among the cattle fed upon its produce.

"5. That this immunity exists, because the conditions necessary for the propagation and continuance of those disease germs which affect man and animals are absent; the microbic life on sewage farms being antagonistic to the life of disease germs, the latter, therefore, soon cease as such to exist.

"6. That sewage farms may be carried on in perfect safety close to populations. It is not, however, argued that the effluent water is safe to use for dietetic purposes.

"7. That there is an aspect in sewage farming, which shows that it is a wise policy for the nation to encourage that form of utilization from a political economy point of view.

"8. That to be financially successful such farms require that the rainfall be separated from the sewage; the area large enough for alternate cropping and the capital employed sufficient to ensure a continuous and rapid consumption of the crops produced.

"9. That, if practicable, sewage utilization by surface irrigation should be, for financial reasons, within the area of its own water-shed and close to the populations producing the sewage; but it is not a necessity that it should be so, provided it be applied to the land within a few hours—not more than twelve— of its discharge, and that there is no arrest of movement for more than very short periods before it is so utilized."

The effect upon health of sewage farming was dealt with very fully by Dr. Carpenter, his remarks closing with this sentence—

"I need not follow this head any further, except to remark that, in February 1887, I submitted a report upon the subject to the Society of Arts in London, in which I conclusively proved that in no single instance, out of nearly 100 cases in which sewage has been utilized by broad irrigation, had any fact been proved to establish the allegations of 'insanitariness' which are sometimes raised against them."

Sewage from isolated dwellings may be disposed of by under-irrigation, that is by distributing the sewage through perforated pipes laid 12 inches to 18 inches below the surface; to these pipes ventilation should be given here and there; or sewage may be led on to sewage filters such as have been described on pages 480 and 491 *ante*.

The following descriptions of the drainage works of Calcutta, Bombay and Madras form a fitting appendix to the foregoing chapter on drainage. The description of the Calcutta drainage scheme is derived from a lecture by the late Mr. W. Clark, the designer of the scheme; that of the Bombay drainage was specially written at the author's request by Mr. Rienzi Walton, lately Engineer to the Bombay Corporation :—

The Drainage of Calcutta.

The city of Calcutta is bounded on the west by a tidal river, the Hooghly; on its north and east by the Circular Canal; and on the south by Tolly's Nullah; it is only on a portion of its eastern side that the open country is not cut off by some navigable and tidal stream.

The surface of Calcutta has an inclination of nearly 3 feet per mile from the river towards the east.

The highest water in the canal is about 4 to 5 feet lower than that in the river; thus the best natural outfall for storm water, because subject to the least tidal obstruction, is towards the east. This is an important peculiarity in the site of Calcutta, as it allows of a natural or gravitating outfall for heavy storms, though the nearly flat and depressed surface necessitates pumping, or an artificial outfall for the sewage at all other times, and during the dry season.

The most advantageous arrangement, therefore, was to follow the natural, though slight, inclination of the surface, and to lay out a system with its general inclination towards the east as the surface falls; and this has been done.

The plan shews five large sewers extending from the river through the town to the east, and all uniting in the Circular Road at the end of Durrumtollah Street.

These are the *first-class* sewers; their inclination is from 2 to 3 feet per mile, and about that of the surface under which they are laid. This small inclination has a double object; it permits the escape of storm water into the river whenever the tide will permit, and it enables these sewers to be more or less flushed, if necessary, twice nearly every day in the year, by admitting the water from the river.

This is occasionally necessary, because the small fall given to them barely suffices for the removal of the heavy sandy solid matter, which is washed into them from the road surface.

Into these large sewers, the *second-class* sewers are discharged; the general arrangement of these latter is to divide the surface of the city into square areas by placing them under the leading thoroughfares.

They have a minimum fall of 6 feet per mile, sufficient to insure their self-cleansing action, when receiving the storm water, and the drainage in the dry season from private dwellings, when furnished with a sufficient water-supply.

Into these *second-class* sewers the smaller *third-class* or pipe sewers discharge; they are laid into all the narrow and tortuous lanes and streets of the city, and their inclination is from 1 in 400 to 1 in 100, or at the rate of from 13 to 50 feet per mile.

The total length of the sewers entirely completed is as follows:—

First class	10¾ miles.
Second class	23 ,,
Third class	79 ,,

The office of the sewers, whose general arrangement has been described, is threefold:—

1*st*.—To remove the subsoil water.
2*nd*.—The drainage of houses.
3*rd*.—The rain water.

The first of these was by no means the least important. If a hole be dug 7 or 8 feet deep, in almost any part of Calcutta, remote from one of the sewers, and carefully observed during the varying seasons of the year, it will be found that the surface of the water, which will immediately collect in it, will vary from a few inches below the surface of the ground in the rainy season, to a few feet, at most 5 or 6 in the month of May. Such trial holes will show only a trifling difference in different localities.

It is this subsoil water which causes damp houses, which by its evaporation produces a damp atmosphere, and it is in

consequence of its usually greater depth from the surface during the hot weather, that the superior healthiness of that season is attributable; hence the deeper the sewer the greater its efficiency for this purpose.

Secondly.—The sewers are intended to remove the house drainage, and this includes all the filthy water from the cook-room and stables, all fæcal matters, bath-room water, &c., and is in quantity usually estimated by the water-supply. For this purpose and for the removal of rain water, small stone-ware pipes are laid from the houses to sewers, and never with an inclination less than 1 in 120: this fall is found to be sufficient, but more is desirable, and obtainable in almost every case.

The third office of the Calcutta sewers is to remove the rain water falling on the surface, and their capacity for discharge is calculated to be equal to quarter inch of rain per hour. This is an enormous quantity, and would, if collected, be represented by a running stream 40 feet wide, 8 deep, and flowing at a velocity of 4 feet per second.

Among the criticisms which have been passed on the system, is the enormous size and cost of the sewers to convey so large a quantity; it had, however, to be provided for in some way or other; either new channels must have been formed, or the abominable ditches and side drains, as they existed for many years, must have been allowed to remain; few persons would have advocated stagnant receptacles for filth a source of nuisance and disease; in fact, any scheme which failed to render them unnecessary would have been liable to the charge of a want of a completeness, and therefore of success. As, however, some provision had to be made for conveying away the rain water, the question resolved itself into the reconstruction of these ditches and surface drains for this especial purpose, or the combination of the entire drainage waters, that of storms with the house drainage and the subsoil water.

The result of a careful inquiry as to the cost of the separate and combined plans induced the adoption of the latter course; as, however, there are many advocates for surface drains, it may be considered what those surface drains would have been like. Granting that they would fall into the river at one end and the canal at the other, it would be inevitable that the greater number of them would be nearly 2 miles long. Now to carry away the storm water and the road debris, and keep themselves clean, they would have required a fall of not less than 6 feet per mile. It is very evident then that, when 2 miles long, they would have been about 10 to 12 feet deep at the lower end; and if only 1 mile long, 5 or 6 feet deep: they would, in fact, have been dangerous chasms occupying a considerable portion of the road surface, and if covered, would have formed a second system of sewers for storm water.

Suppose their fall had been reduced to 3 feet per mile, then must their capacity have been largely increased, and they

would have occupied most inconveniently a large portion of the road surface.

Again, it will be seen that upwards of two-thirds of the entire length of the Calcutta sewers do not average a larger size than a 12-inch stoneware pipe ; few people will be found to quarrel with this as being too large.

The whole objection then, as to the size of the sewers, is comprised within one-third of their total length ; but this must be still further reduced, because with the disappearance of the first-class sewers from the scheme, a total alteration in the arrangement of levels would be necessary, reducing the fall of the whole or involving a greater depth at the pumps, and increased cost of pumping : this would have been highly objectionable. To preserve the present level and falls, the arrangement had also to be preserved and this would have involved, under any circumstances, the construction of large brick sewers in the position of the first class, having the same fall as these have, and upwards of one-third of the total length of the present brick sewer arrangement. The question thus became still further narrowed to the point whether 23 miles of deep brick sewers shall be constructed, out of 113 miles, or about double that length as a separate rain water system only nearer the surface ? Any one will see that the plan of greatest economy and of efficiency also has been adopted.

Some of the details connected with the sewers in the town may now be mentioned. In order to inspect their operation, to detect and remove obstructions, should they occur, SIDE ENTRANCES to the brick sewers are provided about every 1,000 feet and near to junctions. Besides this mode of inspection all the sewers, whether of brickwork or stoneware pipes, can be opened from the surface at MAN-HOLES situated not more than 200 feet apart, and covered with a cast-iron cover ; these man-holes admit of cleansing operations, should such be necessary, without breaking up the road. Thus every part of the system is capable of being examined and cleaned.

The sewers are also provided with ventilating grids ; these are fixed in the centre of the roads ; their office is to allow the escape of the air from the sewer, on the occasion of any sudden rush of water into it, which would of course displace a quantity of air equal to itself in bulk and so prevent the passage of air into the house drains. As a further precaution against this latter contingency, some few iron pipes have been fixed in places considered unobjectionable, by which an interchange of the sewer and the external air can gradually take place, and the diffusion of the former be effected. When the whole system of sewers is fairly in operation, and made to convey away fresh filth, the general adoption of this plan is productive of no nuisance whatever, and the most abundant ventilation possible has been obtained as the result.

GULLIES.—These are pits situated for the most part just outside the kerb stones of the foot-path. They are from 6 to 8 feet deep for the purpose of receiving the storm water, as it flows from the street surfaces, through the iron grids which cover them ; an overflow pipe is connected with the sewer from near the top of the gully, and the heavy particles of road grit are thus arrested. This deposit is excavated from time to time ; notwithstanding this, however, some hundreds of tons of road grit finds its way to the pumps on the occurrence of every shower.

HOUSE DRAINS.—Every inlet to these is guarded by a grating, and a pit or trap acting on the syphon principle, so as to admit filthy fluid to pass inwards, but prevent the escape of the air outwards.

Many persons look upon these arrangements with suspicion, as a means of conducting impure air into the houses from the sewers. To prevent this, however, the house drains are furnished with an especial trap, near the inlet to the sewer, which effectually prevents it.

The system of sewers has been now generally described within the town ; and it remains to describe the outfall works from the point of junction between the Circular Road and the Durrumtollah main sewers. At the end of the latter street, the three are all united in one called the 'canal outfall sewer,' as it occupies the position of what was formerly the Entally branch canal ; this canal terminated in what was generally known as the cess-pool of Calcutta—an accumulation of filth happily no longer existing—not far from the Circular Road.

This CANAL OUTFALL is a formidable work ; it is 3,284 feet long. Its construction became necessary in consequence of an order of the Bengal Government, which fixed the neighbourhood of Palmer's Bridge as the limit, within which the pumping station would not be permitted ; moreover, the portion of the drainage works then constructed was not allowed to be used until this large sewer and the whole of the outfall works were completed. This was in May 1861, and undoubtedly considerable delay in testing the efficiency of the scheme by actual use was thereby incurred ; and also a large additional expenditure of money, on works which up to that time, were considered experimental only.

This canal outfall sewer has a fall of 2 feet per mile, and at its lowest level is 15 feet below the average level of spring tides during the rainy season.

SILT PITS AND PUMPING STATION.—At its eastern end, the canal outfall sewer bifurcates, each of its continuations is protected by a gate ; and either or both of them can be used as occasion requires. Just within the gate, the invert has a sudden drop of 3 feet, and then falls to a further depth of 8 feet ;

thus two large receptacles, 150 feet long, are formed with a sloping bottom to the eastern end, and each becomes a pit in which silty and solid matter is arrested. This provision was made in conformity with the orders of Government, and to prevent the silt, as far as practicable, from being washed into the canal on the occasion of storms.

The eastern ends of the SILT PITS, as this arrangement is called, are protected by another pair of gates like those before alluded to, but taller to shut out the canal water; they can be lifted by suitable gearing from above. The intention was, if need be, to allow barges to enter from the canal to take away the silt; this, however, has been unnecessary, and the gates are only used during the time of heavy storms, when the engines are overpowered by the quantity of water coming down from the town; they are then lifted and the storm water escapes into the canal. Under the gate platform a culvert is constructed, leading to a well, from which also the suction pipes are laid; by this arrangement either pump can work either pit.

The pumps and engines are combined, the former on the centrifugal principle. All the parts of the engines and pumps are secured to a large vertical tank, at the bottom of which the centrifugal disc works. The action is this: the disc receives the fluid at this centre, and revolving with great rapidity, throws it out at the periphery, with a force, which causes it to rise within the tank, to such a level as to overflow into the high level sewer, which conveys it from the pumping station to the Salt Water Lake. As it escapes from the pumps it passes through a surface condenser connected with the engines, and by this means the condensation of the steam, which works the engine, is effected.

The large quantity of silty matter conveyed by the sewers to pumping station, rendered some especial provision for its disposal necessary; this is effected by the SILT AGITATOR. The apparatus consists of a series of pipes laid along the invert of the silt pits, and to every part of the arrangement where silt is likely to occur. These pipes are furnished with nipples. They are connected with a pair of air-blowing cylinders, and a pump worked by a small auxiliary engine; by these means air or water can be forced through the pipes, which escaping at the nipples puts all the silt and fluid around them in a state of ebullition and mixes them up in a state to be pumped.

The surface condensers are also kept clear of deposit in the same way. The chambers over the pits are now generally kept closed, and are ventilated by a flue, which conveys the air from the pits to the boiler furnace, through which it passes to the tall engine chimney.

The high level sewer is 8,284 feet long, and is capable of conveying about two million gallons per hour; its fall is 4

feet per mile; it terminates in an open excavation through the square mile of area reclaimed from the Salt Water Lake, which is 8,900 feet long; and at its eastern extremity, distant 3¾ miles from the Circular Road, this open channel communicates with a natural stream.

An enormous quantity of silt accumulated in this open channel during two years, and by far the greater part during one rainy season. A careful measurement showed it to be no less a quantity than 1,400,000 cubic feet which had passed through the pumps, and necessitated the re-excavation of the channel. It chiefly consisted of the debris from the road surface of Calcutta, mixed with feculent matter; this large accumulation proves the power of the streams running in the sewers to transport it and to keep them clean; they have done so to the present time in a most satisfactory manner: the result is precisely that which was intended.

Some sanitarians still look with doubt on this means of disposal, and are apprehensive that the large quantity of sewage so voided into the locality, called the Salt Water Lake, will be productive of evil consequences. This mixing of the sewage with the natural stream is, however, absolutely unnecessary, and may be avoided, by its utilization on the reclaimed area, which was taken up for this especial purpose; this area may be extended as necessity requires hereafter; as the 28 square miles of the swamp, called the Salt Water Lake, is more than sufficient for the purpose.

Notes on the Sewerage of Bombay.

The population, according to the census of 1881, is 773,196. The sewers have been designed for a population of one million.

The area is 22¼ square miles.

The average annual rainfall for the past 60 years is 78 inches and the rains occur only in June, July, August and September (four months). Drains of sufficient capacity to carry both storm water and sewage would be inefficient during the dry season, which extends over two-thirds of the year. The segregated system has, therefore, been adopted. Drains of large capacity carry storm water only, and sewers of smaller capacity carry sewage only.

The water-supply is obtained from two artificial lakes—the Vehar Lake, 15 miles from Bombay, and the Tulsi Lake, 18 miles from Bombay.

The average daily water-supply is 19 gallons per head.

Masonry sewers are constructed along the valley lines of the district. They are ovoid in shape of the following proportions:—

Internal transverse diameter at the springing of covering arch = T.

Internal height = $\frac{3\,T}{2}$.

Radius of invert = $\frac{T}{8}$.

Radius of internal perimeter of walls or sides = $\frac{4\,T}{3}$.

Radius of soffit of covering arch = $\frac{T}{2}$.

The inverts are of béton or cast blocks of concrete from 7 inches to 9 inches thick in the thinnest part and about 18 inches long. The béton is composed of Portland cement 3, sand 4, clean river shingle 4, and broken stone 4.

The sides or walls are of concrete deposited *in situ* from 9 inches to 14 inches thick. The concrete is composed of Portland cement 2, lime 3, sand 6, clean river shingle 6, and broken stone 6.

The covering arches are of brickwork from 9 inches to 14 inches thick. The mortar (hydraulic) is composed of lime 4, ground pumice 1, and sand 4.

The internal transverse diameters of the sewers are variously 30 inches, 32 inches, 40 inches, 46 inches, 56 inches, and 64 inches.

The gradients vary from 1 in 1,000 to 1 in 2,200, and are designed to procure a velocity of from 2½ feet to 3 feet per second when the sewers are running two-thirds full, that is, filled to the springing line of the covering arch.

At a distance of 2,000 feet from the outfall, the sewage is pumped by steam power through a vertical rise of 26 feet and discharged by gravitation from the pumping station to the sea at a secluded spot on the shore where the currents are favourable to the transportation of the sewage.

From the pumping station to the outfall well on the sea shore the sewer is of masonry double cylindrical in shape, each cylinder being 42 inches in diameter.

From the outfall well the sewage is discharged into a double line of 36 inches cast-iron pipes 870 feet long, the end being 6 feet below low-water level at spring tides.

On the masonry sewers a man-hole is provided at the junction of every tributary pipe sewer, and where such pipe sewers are more than 200 feet apart, intermediate man-holes are introduced, so that no two man-holes may be more than 200 feet apart.

Each man-hole is provided with a groove sunk in the invert and walls of the sewer, to receive a wooden flushing door. The

doors are made in vertically divided leaves and are collapsible. The doors dam back the sewage, and whatever water may be added, and on being caused to collapse are suddenly withdrawn and a flush is obtained.

At four points which conveniently presented themselves, a communication has been made with the sea and sea water is admitted at pleasure for flushing purposes.

Ventilation is obtained by rectangular tubing 14 inches × 4 inches, laid from the man-holes where convenient, and carried up the sides of houses to about 5 feet above the roof. The tubing is of either cast-iron or masonry underground; the first length above ground is of cast-iron, and the upper part of zinc. The tubing is divided into two equal parts by a diaphragm or partition.

The tributary pipe sewers are circular and of glazed stoneware. They are 9 inches, 12 inches, 15 inches and 18 inches in internal diameter; the last two sizes are rare.

The joints are made by forcing tarred gasket into the sockets around the spigots and filling up with neat Portland cement finished off with a small splay around the rim of the socket.

The minimum depth of a pipe sewer is 3 feet between the surface of the ground and the top of the pipe.

The gradients are as steep as is practicable and convenient, but the flattest gradients are such as will give a velocity of 3 feet per second when the pipe is either full or half full.

Circular man-holes 5 feet in internal diameter at the bottom and constructed of brickwork are provided at every deviation from a straight line and wherever another pipe sewer joins. All pipe sewers are laid in perfectly straight lines.

At the head or highest part of a pipe sewer there is always either a man-hole or a lamp-hole.

Intermediate man-holes and lamp-holes are introduced, so that no two man-holes or a man-hole and a lamp-hole are more than 200 feet apart.

No two lamp-holes ever follow in direct succession; there is always one man-hole or more between any two lamp-holes.

Circular man-holes more than 5 feet 6 inches in depth are conical in form; if 5 feet 6 inches or less in depth they are domical.

The floors of the man-holes are formed of Portland cement concrete with half round channels corresponding in size with the diameter of the pipes.

Any man-hole can be filled with sewage and water by stopping the socket of the outlet pipe with a padded wooden disc; to the disc an iron strut bar with a rule-joint is attached: this can be acted upon by a chain and if suddenly pulled up when the man-hole is full a flush is produced.

Cleansing instruments, such as spades, hoes, hooks and balls attached to interlocking bars, are used in pipe sewers when occasion requires.

Lamp-holes consist of 9-inch stoneware pipes placed vertically covered with suitable cast-iron covers.

The pipe sewers are ventilated by ventilating tubes corresponding exactly with those used on the masonry sewers.

There is always an element of danger in working in sewers, particularly in a hot climate, and it should be avoided as much as possible. In hot still weather, there is probably as much danger from the exhaustion of oxygen and exhalation of carbonic acid by the workmen themselves as from gases generated by putrefaction. Form 'G 86' (following) contains a list of precautions to be observed in working in sewers. No accident has taken place when a diver's air-pump and tube have been kept in action.

Form 'A 86' (following) fully explains the system of house connections. It will be observed that open joints or breaks of connection are in all cases insisted upon. No house is directly connected with a sewer, there is always a break of connection between the one and the other. 'Náhanis' are low sinks or bathing places generally level with the floor and surrounded by a raised curb.

European water closets are used to a limited extent.

Native water closets with long narrow pans designed to suit a squatting posture are being gradually introduced.

Native privies generally consist of a stone floor with a raised stand or foot place in which there in an open slit about 6½ inches wide. Beneath the slit is a basket into which the fæces fall. The baskets are collected by 'sweepers' from the back of the privies through a small door.

The sweepers convey the night-soil to depôts, where they throw it into iron cylindrical carts.

The carts are despatched periodically to a main depôt not far from the head of the main sewer and emptied into tanks.

Sea water previously pumped up into and reserved in other tanks is admitted into the night-soil tanks to dilute the night-soil, and the whole is then discharged into the sewer.

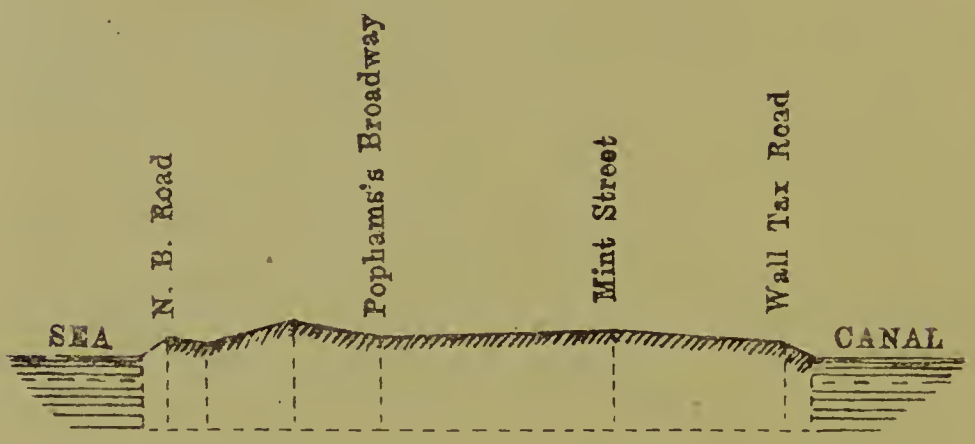
These conditions of the admission of night-soil into the sewers are the most disadvantageous possible; they are the outcome of old arrangements which cannot all at once be set aside.

Drainage of Black Town, Madras.

The city of Madras is divided into eight divisions, of which the second and third divisions comprise Black Town, an area of

1·65 square miles averaging 1½ miles in length and somewhat more than a mile in breadth and containing a population in 1881 of 128,000. The second division having an area of 0·74 square miles is that furthest from the sea and contains 77,000 people; the third division, lying along the sea, has an area of 0·91 square miles and contains 51,000 people. The average population per square mile in the former is 104,054 and in the latter 56,044.

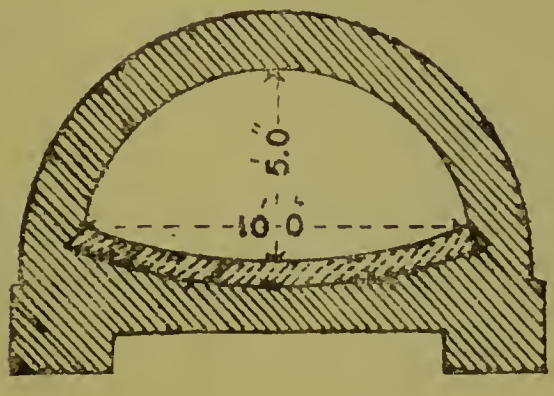
Through Black Town, parallel to the sea, run two ridges as shown in the accompanying section taken west to east across Black Town :—



A street called Popham's Broadway occupies a valley running north and south and is from 6 to 8 feet above mean sea level, the ridge next the sea is 21 feet and that next the canal 13 to 20 feet above mean sea level.

The difference between high and low spring tides is 3·19 feet.

The drainage is so arranged that the *rainfall* is carried into the valley or to the eastern and western slopes and then passed, not into the sewers hereafter to be described, but into the canal on the west, the sea on the east, and into a large drain in the central valley called the Black Town main drain which, designed to carry off sewage, will now be used for rainfall alone. This drain is of the following section, 10 feet wide and 5 feet high; its invert at its highest point is only 1·7 feet above mean sea level; it flows from the centre of the town and discharges itself both south and north of the town. The southern portion was constructed in 1805 and the northern in 1840. From the section it will be seen that it is quite unsuited to the purpose for which it was designed, but is suitable for discharging large bodies of storm water.

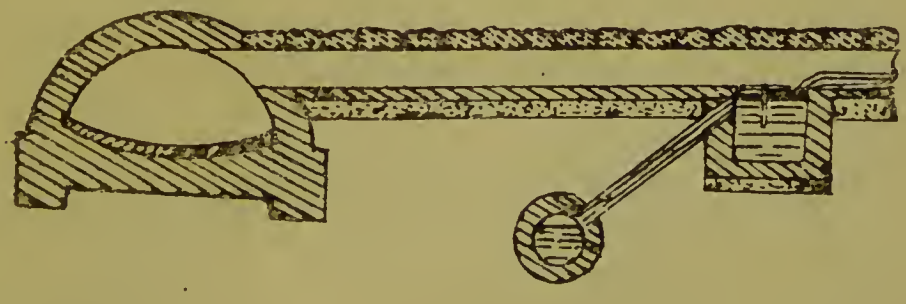


The plan adopted for the Black Town drainage is of a somewhat novel character in so far as, that, while the same street drains carry both sewage and rainfall, the sewage flows off by the new set of sewers and the rainfall as already described. In ordinary cases sewage alone is found flowing in the street drains, and during rainfall a partial division is effected, the upper or lighter and less contaminated water passing off by existing outlets and the lower or sewage water with a small percentage of rainfall into the new sewers.

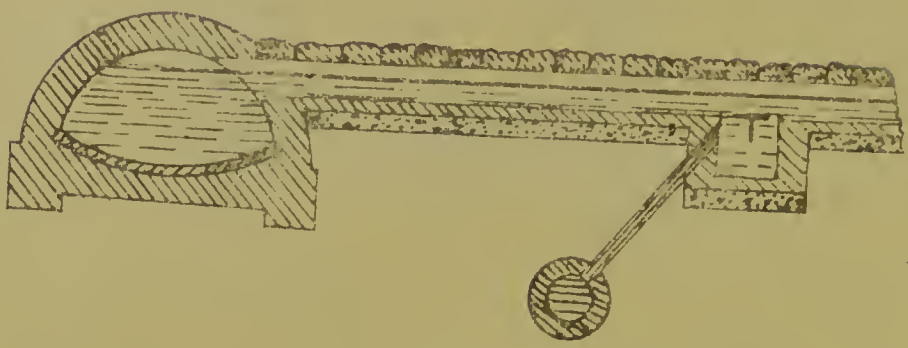
From the section given above, it will be observed that east and west the inclinations are considerable; the ridges have also a slope north and south. Proper slopes for the street drains were, therefore, in most cases easily obtainable. In certain cases however, streets had to be re-graded and sometimes house floors, and backyards raised; the lower floors of houses in Madras are however generally high above street level and not much difficulty was experienced.

When the street drains are running full with rain and sewage water, these matters pass on together until they reach the valley or the foot of the eastern or western slopes. The division then takes place as in the following sketch :—

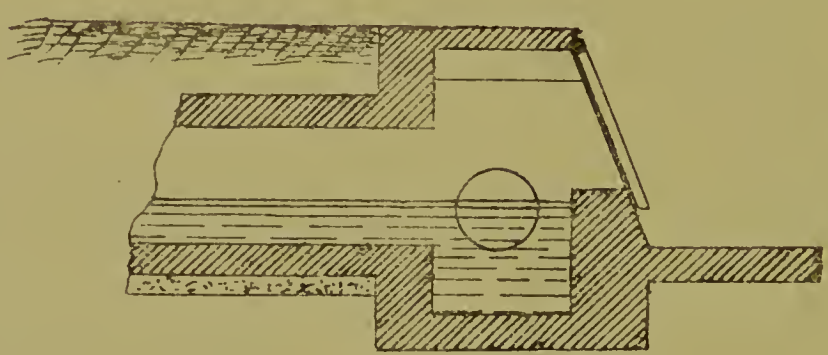
Section showing all sewage flowing to sewer in the valley.



Section with storm overflow in action.

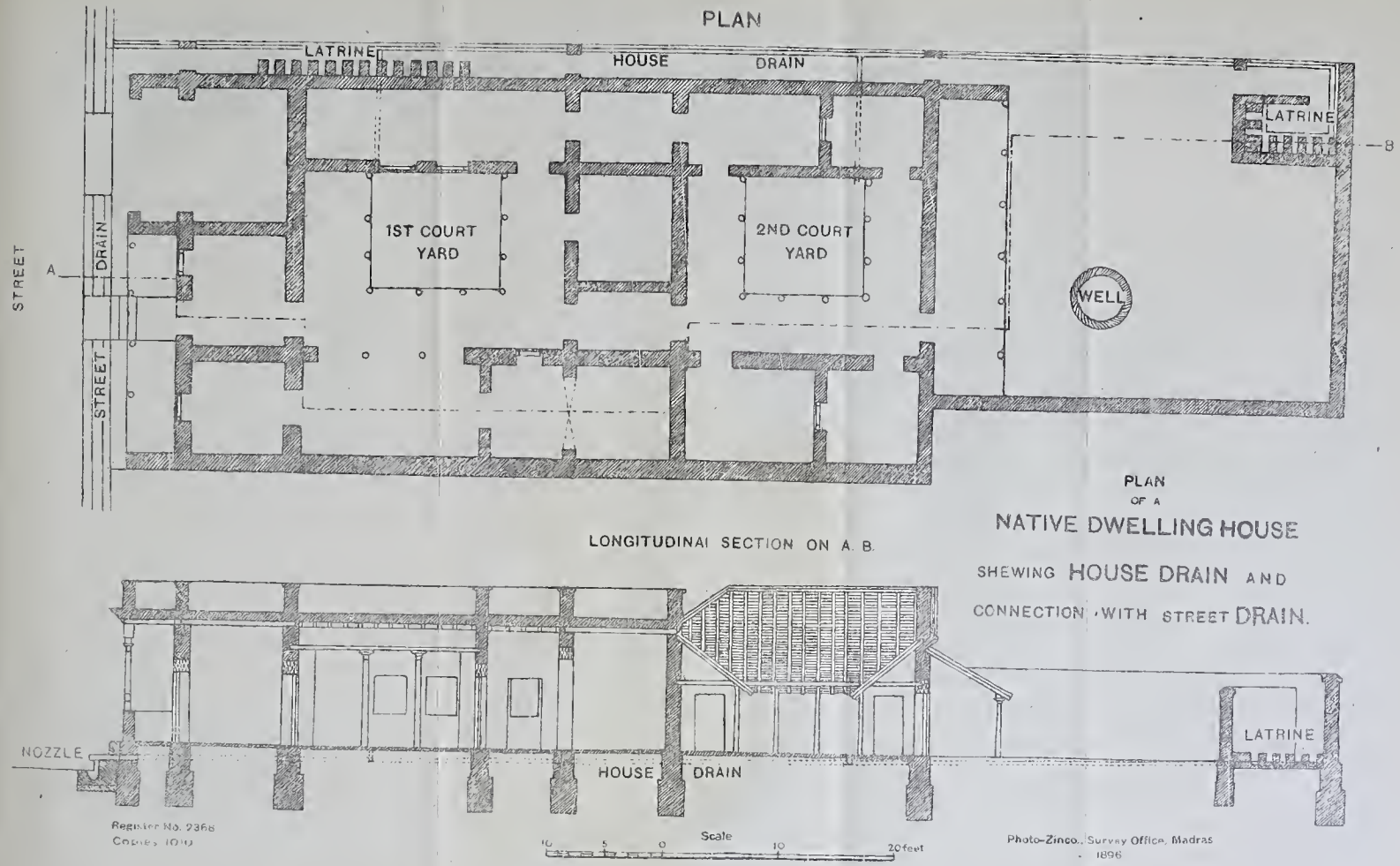


At the foot of the eastern and western slopes the arrangements are slightly different and are as per following sketch, the storm waters discharging into the canal or sea when rising above the ordinary sewage flow :—



It is proposed to introduce mechanical arrangements for more effectually controlling the quantity to be allowed to flow into the sewers during rainfall.

The street drains are constructed of country bricks and chunam. Country bricks lend themselves more readily to the construction of the smaller drains. All drains are, however, capped by English bricks in cement, and all the drains are plastered inside with cement 3 to 1 and finished with neat cement.

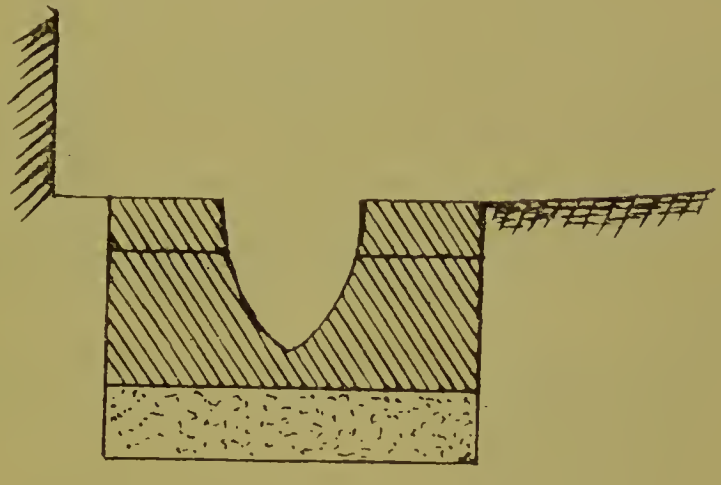


PLAN
OF A
NATIVE DWELLING HOUSE
SHEWING HOUSE DRAIN AND
CONNECTION WITH STREET DRAIN.

Register No. 2366
Copies 1010

Photo-Zinco., Survey Office, Madras
1896

The street drains are of the following section and vary in size from 6 inches to 24 inches. They are always of the same breadth as of depth.



The sizes are determined with reference to their inclination, so that they shall carry off half inch per hour from the area drained.

The advantage of open street drains for the reception of house sewage is this (no excreta enters these drains, such matters are separately removed and no water closets exist in the city), that no elaborate arrangements are necessary as with closed pipe drains to prevent the gas evolved from the sewage entering the houses and no danger from sewer gas exists.

The house drains are connected to the street drains as shown on the accompanying plate.

There are only three sewers in the scheme, one to the east, one to the west, and one somewhat contiguous to the main drain in the Popham's Broadway valley. These sewers vary in size from 12 inches to 18 inches (glazed stoneware pipes) and from 24 inches to 36 inches (brick sewers); they are designed so as to secure a minimum velocity of 2 feet per second. The brick sewers are constructed of 9 inches of brickwork in cement and are plastered inside and outside with cement. The stoneware pipes are laid on concrete and jointed with cement mortar in the proportion of 3 of sand and 1 of cement.

The sewers are furnished with the usual man-holes, flushing doors, ventilators, &c.

These three sewers converge to a pumping station to the north of the town, where the sewage is pumped up by powerful engines into a 24-inch diameter iron main, which conveys the sewage to a further distance of a mile and a quarter. It

is then discharged into an open masonry channel which is in length 1½ miles; the sewage is drawn off at various points and used for private irrigation or finally drawn off on to a municipal sewage farm. None of the sewage reaches the sea.

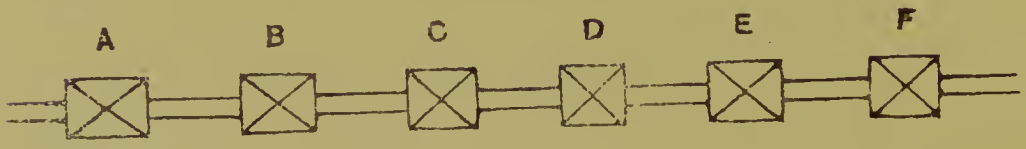
FORM G. 86.

Precautions ordered to be taken in Bombay in entering and working in Sewers or Drains.

1. The first duty of the Inspector or other person in charge is to see that he has supplied himself with the following appliances:—

(*a*) Chemical test-papers for sulphuretted hydrogen gas.
(*b*) Lights.
(*c*) Bamboos.
(*d*) Wind-sails.
(*e*) Strong ropes and cords.
(*f*) Diver's air-pump (or smith's bellows).
(*g*) Air-tubing.
(*h*) Picks, paoras, pails, gamels and whatever implements may be required for the actual work.

2. The following sketch of a sewer, with a series of six man-holes in succession (A, B, C, D, E and F) will illustrate the system to be adopted:—



3. All the six man-holes must be open for free ventilation for an hour or more before a man enters the sewer.

4. At B and also at E, a wind-sail must be erected with the flaps kept distended towards the direction from which the wind blows.

5. The work will commence either at C and proceed towards D or at D and proceed towards C.

6. Assuming that the work begins at C, then a diver's air-pump or a pair of smith's bellows with a flexible air-tube must be set up at C and kept constantly at work.

7. A competent man must be placed in charge of the work, and he must satisfy himself by inspection at the first and from time to time that the sewer is not dangerous to work in.

It must be remembered that, although near a man-hole the air may be pure, yet farther within the sewer it may be fatal to life.

8. Chemical papers for testing the presence of sulphuretted hydrogen gas are to be obtained from the Municipal office. If a paper after five minutes' exposure in the sewer turns a deep brown or black, the sewer is dangerous to work in.

9. If the paper-test is satisfactory, a light must next be let down into the sewer, and it is always to be kept 20 feet in advance of where the men are at work; they are to be cautioned to observe that it burns properly.

10. If it burns unnaturally or goes out, the men are not to descend; or if they have descended, are to return to the nearest man-hole immediately.

11. Each man is to be fastened by a stout rope passing under his arm-pits and with the knot against his spine. The rope is to be kept from slipping down to the lower part of the body by means of short pieces of cord passing over the shoulders. The loose end of the rope is to be kept on the surface of the ground.

12. The foremost man must have the end of the air-tube, always a little in advance of him, and he must carry it himself if possible; should the latter not be found practicable, another man must be employed to carry the air-tube.

13. In any case one man must always be stationed at the bottom of the man-hole to give an alarm and render assistance, if required.

14. The men are to be cautioned that if they feel any difficulty of breathing (or feel unwell in any respect), they are not to remain in the sewer, but to come out immediately.

15. No man is to be allowed to remain in the sewer more than half an hour at a time.

16. At least three men must be stationed on the surface at the man-hole from which work is being carried on.

17. The men must be warned against either urinating or defœcating in the sewer.

18. When the work has been completed from C to half the distance between C and D, the work will be begun from D and proceeded with towards C, precisely similar arrangements and conditions being observed.

19. These instructions for executing the work between C and D will apply to carrying out the work between any other two man-holes, the wind-sails, air-pump, or bellows, and other appliances being moved as required.

20. Should an accident occur, every person in the sewer must be brought to the surface at once, and whilst they are so being brought out, crowding around the man-hole must be prevented because a crowd would check the escape of the foul air or the entrance of fresh air.

21. If any person brought out of the sewer is insensible and medical attendance cannot be immediately obtained, the following treatment of the sufferer should be adopted :—

(*a*) Loosen all clothes about the body.
(*b*) Dash water on to the man's face turned towards the wind.
(*c*) Lay the man flat on his face with one of his arms under his forehead.
(*d*) Open his mouth, draw his tongue forward, and cleanse his mouth and nostrils with water.
(*e*) Turn him on one side while supporting his head, and turn him back again on his face.
(*f*) If breathing does not commence, turn him again gently on to one side and then on to his back.
(*g*) Raise his head and shoulders.
(*h*) Grasp both his arms just above his elbows and draw them gently but firmly upwards above his head and keep them in that position two seconds.
(*i*) Lower his arms and press them gently against his side.
(*j*) Continue to raise and lower his arms as described until breathing is restored or until the man is placed in charge of a doctor.
(*k*) If breathing is restored before a doctor is obtained, rub the man dry and wrap him in dry warm clothes. Do everything possible to restore warmth and circulation.
(*l*) As soon as the man can swallow, give him warm water or any kind of spirit to drink.

22. The sufferers are to be promptly conveyed to the nearest medical man or the nearest hospital. Early medical attention is very essential.

23. As soon as the sufferers have been placed under medical care (or earlier if a messenger is available), information must be sent to the Executive Engineer.

FORM A. 86.

Rules for House Drainage (Bombay).

1. Permission to carry out the drainage of house No.——— in——————— will be granted on the following conditions.

2. That every náhani be fitted up with a 4 inches by 4 inches C.I. (cast-iron) grating, securely fixed in a vertical position from the inside.

3. That every náhani, every urinal and the night-soil chamber (or other receptacle of urine and ablution water) of every privy be provided with a 2½-inch C.I. ventilating (open-ended) discharge pipe firmly fixed from the outside.

4. That every discharge pipe be made to dip into a C.I. cistern head to the extent of 1 inch below the rim of the cistern head. (*Note.*—In the case of a discharge pipe from a náhani, urinal, or privy on the ground floor, the cistern head may be dispensed with.)

5. That every cistern head be connected with a 2½-inch C.I. down-take pipe. (*Note.*—In the case of a náhani, urinal, or privy on the ground floor, if without a cistern head, the down-take pipe must be connected directly with the discharge pipe.)

6. That the bottom end of every down-take pipe be made to dip into one corner of a stoneware gully trap to the extent of 1 inch below the rim of the gully trap.

7. That every gully trap be so fixed that its rim may be 2 inches above the paving or ground around it.

8. That a 6-inch stoneware pipe drain with all necessary junctions and bends be laid about the premises when required, and from the premises to the municipal sewer in——————— with a gradient of as nearly 1 in 50 as possible. (*Note.*—No drain will be allowed inside the house or within any covered portion of the premises.)

9. That at the head of the pipe drain a 6-inch by 6-inch stoneware junction be provided for the purpose of cleaning and flushing it, the end and branch of the junction being so covered as to be easily accessible.

10. That if the pipe drain deviate from a straight line or be more than 50 feet in length, an inspection chamber be constructed at every point of deviation and at every 50 feet in length (at the most) with an inlet brought up to within 6 inches of the surface and so covered as to be easily accessible.

11. That the gully traps be connected with the pipe drain by 4 inches stoneware pipes or bends.

12. That where the pipe drain leaves the premises and passes under the roadway, a 6-inch stoneware syphon be inserted in the line of the pipe drain with a 4-inch inspection inlet

carried up to within 6 inches of the surface and so covered as to be easily accessible. (*Note.*—All syphons must be laid level.)

13. That one 2½-inch C.I. ventilating pipe be connected with the head of the pipe drain and another with the pipe drain between the syphon and the municipal sewer, and that both be (*a*) carried at least 10 feet higher than any sky-light or window situated within a distance of 20 feet therefrom; (*b*) carried higher than the highest part of the building, if any, to which it is affixed; and (*c*) erected or affixed so as to create the least practicable nuisance or inconvenience to the inhabitants of the neighbourhood.

14. That before any part of the roadway be disturbed, the applicant pays the usual road-opening fee into the Executive Engineer's office and obtains a permit.

15. That the said permit be produced to the Inspector of drains at his office during his office hours, and that an arrangement be made with him to attend at the premises to see the making of the connection with the municipal sewer.

16. That no connection be made with the municipal sewer, and that the municipal sewer be not exposed, except in the presence of the Inspector of Drains.

17. That, in the event of a special junction being required with the municipal sewer, the applicant provides and fixes (*a*) a stoneware junction pipe of the necessary size, (*b*) a 6-inch stoneware junction block.

18. That all joints, both of stoneware pipes and iron pipes, be made air-tight and water-tight.

19. That the paving of sweeper's passages be laid at a gradient of at least 1 in 80, and that the joints be pointed with Portland cement. (*Note.*—Any paving that may be disturbed must be carefully restored and the joints pointed with Portland cement.)

20. That, as there is a raised foot-path at the side of the road, a stoneware gully trap be placed at the lower end of every sweeper's passage (the rim of the gully trap to be 1 inch lower than the paving), and connected (*a*) by means of a 6-inch stoneware pipe drain, laid at a gradient of as nearly 1 in 50 as possible, with the separate municipal drain provided for storm water, or intended to be used ultimately for storm water only. (*Note.*—Paragraphs 16, 17 and 18 are to be applied to this case, the word 'drain' being substituted for 'sewer'); (*b*) with the drain referred to in paragraph 8, the connection being made on that part of the drain which is higher than the syphon referred to in paragraph 12. (*Note.*—Paragraphs 11 and 18 are to be applied to this case.)

21. That the whole of the work be done according to the instructions of the Municipal Inspector of Drains.

CHAPTER IX.

LOANS.

Object of raising loans.—As all permanent works are undertaken, not only for the benefit of the existing population of a district or town, but also for future generations, it is but right and proper that a portion of the cost of such works should be paid by the latter as well as the former. This object is attained by raising loans to meet the cost of such works, such loans extending over periods twenty, forty, fifty or hundred years as the case may be.

Method of repayment.—It is usual to provide for the liquidation of such loans by annual or half-yearly payments, which form what is called a sinking fund. These amounts deposited in a bank will bear interest yearly or half-yearly, and the amount excluding interest required to be so paid, in order to liquidate the loan, at the end of the period agreed upon, will be *very much* less than the amount of the loan divided by the number of years during which the loan exists. This is not difficult to understand if it is remembered that compound interest is being obtained.

Tables for facilitating calculation of periodical payments.—Tables Nos. I and II towards the end of this chapter have been drawn up to facilitate the calculation of the amounts necessary under varied circumstances. Payments towards the sinking fund are supposed to be made yearly or half-yearly according as the interest is paid annually or every six months.

Method of using the tables.—The method of using the tables is as follows:—Suppose it is desired to ascertain what half-yearly payment is required to liquidate a loan of Rs. 1,00,000 in 50 years by 100 payments, bearing interest at 2 per cent. per half-year. This is to be found from table I, thus; opposite 100 and in the column headed 2 per cent. will be found the figures ·0032, these multiplied by 100,000 will give 320, or Rs. 320 is the half-yearly payment required. If the payment is to be annual, and interest is to be paid on sinking fund at 4 per cent. per annum, look in Table II

and opposite 50, the number of years and the number of payments will be found in the column headed 4 per cent. the figures ·0066, these multiplied by 100,000 give the number of rupees, viz., Rs. 660 required to be paid yearly.

Rate of interest on what basis to be fixed.—The rate of interest, which it is advisable to offer for a loan, depends (1) on the state of the money market, (2) on the security offered. If too low a rate of interest be offered the loan may not be obtainable at par, and on the other hand so favourable a rate may be fixed that the loan may be offered above par; that is, in the former case for each debenture proposed to be issued, say, for Rs. 100, Rs. 98 or Rs. 96 only may be obtainable, while in the latter, Rs. 101, 102, &c., may be offered.

Consideration of tenders for loans.—When loans are tendered far below par or at a discount, it may be necessary to consider whether it is advisable to accept such tenders or call for other tenders, proffering a higher rate of interest. Thus suppose a 50 years' loan for a lakh bearing interest at 6 per cent. is tendered for at 10 per cent. discount, or Rs. 90 for each Rs. 100 debenture, the borrower would only obtain 90,000 instead of 1,00,000 and would thus be paying instead of 6 per cent. $6\frac{2}{3}$ per cent. for the amount obtained.

If then at $6\frac{2}{3}$ per cent. the loan is obtainable at par, the question comes to be whether is it better to accept the tender or to offer $6\frac{2}{3}$ per cent. and thus get 100,000 instead of only 90,000. Suppose the payments to sinking fund are to be half-yearly and bear interest at 2 per cent. per half-year. In the first case the total expenditure would be:—

	Rs.
100 payments to sinking fund at Rs. 320.	32,000
50 payments, of interest at 6 per cent. at Rs. 6,000	3,00,000
Total ..	3,32,000

In the second case—

100 payments as above	32,000
50 payments, interest $6\frac{2}{3}$ per cent. at Rs. 6,666	3,33,300
Total ..	3,65,300

But in the first case 10,000 more has still to be borrowed, we must also take that into account and may consider it thus, for Rs. 10,000 :—

	RS.
100 payments to sinking fund at Rs. 32..	3,200
50 payments, interest $6\frac{2}{3}$ per cent., Rs. 666.	33,300
	36,500
Add as above ..	3,32,000
Total ..	3,68,500

so that it would, in such case, be better to call for fresh tenders if it could be fairly assumed that $6\frac{2}{3}$ per cent. would command the loan at par.

Cost of loans large in proportion to amount borrowed.—The foregoing examples may have called attention to the fact that proportionately large amounts to the sums borrowed have to be expended in paying interest. Table No. III has been drawn up for the purpose of calling attention to this matter, and from it will be seen what large amounts as interest must be paid for borrowed money.

	RS.
From Table III the total interest payable on a 50 years' loan of 1 lakh at 6 per cent.	3,00,000
Sinking fund as before at 2 per cent. per half-year	32,000
Total ..	3,32,000

Period of loan should be limited with regard to financial position.—Probably the shorter the period for which a loan is, the higher will be the rate of interest required, or the loan will be offered at a less premium or a greater discount demanded, but for the purposes of comparison suppose the loan could be obtained for thirty years only on similar terms, the figures would stand thus :—

	RS.
30 years' interest at 6 per cent.	1,80,000
60 half-yearly payments to sinking fund, Rs. 870	52,200
Total ..	2,32,200

showing a saving of nearly a lakh to the community, and the extra burden during that period on the rate-payers would be only 2 (870—320) = Rs. 1,100 per annum, a sum the payment of which would hardly inconvenience any municipality. The longer the period for which a loan is taken the more expensive it is; it therefore behoves corporations no less than private individuals, to pay off what they borrow in as short a time as they conveniently can.

Tables for facilitating the calculation of the amounts at varying rates of interest required to form sinking funds in order to liquidate loans for periods between 20 and 50 years.

Table I.

Half-yearly payments.

Number of years over which loan extends.	Number of payments to sinking fund.	Amount of interest received from sinking fund half-yearly.					
		1¾ per cent.	2 per cent.	2¼ per cent.	2½ per cent.	2¾ per cent.	3 per cent.
20	40	·0174	·0165	·0157	·0148	·0139	·0132
25	50	·0127	·0118	·0110	·0102	·0095	·0088
30	60	·0095	·0087	·0080	·0073	·0066	·0061
35	70	·0074	·0066	·0060	·0053	·0048	·0043
40	80	·0058	·0051	·0045	·0042	·0035	·0031
45	90	·0047	·0040	·0035	·0033	·0026	·0022
50	100	·0039	·0032	·0026	·0023	·0019	·0016

Table II.

Yearly payments.

Number of years over which loan extends.	Number of payments to sinking fund.	Amount of interest received from sinking fund yearly.					
		3½ per cent.	4 per cent.	4½ per cent.	5 per cent.	5½ per cent.	6 per cent.
20	20	·0354	·0336	·0319	·0302	·0286	·0272
25	25	·0257	·0240	·0224	·0210	·0196	·0182
30	30	·0194	·0178	·0164	·0151	·0138	·0126
35	35	·0150	·0136	·0123	·0111	·0099	·0090
40	40	·0118	·0105	·0093	·0083	·0072	·0065
45	45	·0095	·0083	·0072	·0063	·0054	·0047
50	50	·0076	·0066	·0056	·0048	·0040	·0034

TABLE III.

Showing total amount of interest payable on a loan of 1 *lakh of Rupees for various periods at varied rates of interest.*

Number of years over which loan extends.	Interest payable yearly.						
	3 per cent.	3½ per cent.	4 per cent.	4½ per cent.	5 per cent.	5½ per cent.	6 per cent.
	Total interest payable.						
	RS.	RS.	RS.	RS.	RS.	RS.	RS.
20	60,000	70,000	80,000	90,000	1,00,000	1,10,000	1,20,000
25	75,000	87,500	1,00,000	1,12,500	1,25,000	1,37,500	1,50,000
30	90,000	1,05,000	1,20,000	1,35,000	1,50,000	1,65,000	1,80,000
35	1,05,000	1,22,500	1,40,000	1,57,500	1,75,000	1,92,500	2,10,000
40	1,20,000	1,40,000	1,60,000	1,80,000	2,00,000	2,20,000	2,40,000
45	1,35,000	1,57,500	1,80,000	2,02,500	2,25,000	2,47,500	2,70,000
50	1,50,000	1,75,000	2,00,000	2,25,000	2,50,000	2,75,000	3,00,000

Instead of the foregoing system it is usual, in regard to mofussil bodies in Madras, to require principal and interest to be paid yearly in equal instalments, and the amount to be paid under this plan is shown in the following table :—

Table showing the amount of equal annual payments (of principal and interest combined) necessary to cancel a loan of Rs. 100 *at* 3, 3½, 4, 4½, 5 *and* 6 *per cent. payable annually and maturing any number of years from* 1 *to* 30.

Number of years in which loan expires.	Per cent. per annum.					
	3	3½	4	4½	5	6
1	103·000	103·500	104·000	104·500	105·000	106·000
2	52·261	52·657	53·020	53·413	53·780	54·544
3	35·362	35·699	36·026	36·370	36·726	37·411
4	26·903	27·229	27·550	27·877	28·202	28·857
5	21·832	22·147	22·464	22·778	23·096	23·741
6	18·460	18·771	19·077	19·386	19·702	20·337
7	16·049	16·353	16·662	16·969	17·282	17·914
8	14·244	14·548	14·852	15·161	15·472	16·103
9	12·843	13·145	13·450	13·757	14·069	14·702
10	11·723	12·024	12·330	12·637	12·950	13·586

Table showing the amount of equal annual payments, &c.—cont.

Number of years in which loan expires.	Per cent. per annum.					
	3	3½	4	4½	5	6
11	10·808	11·109	11·416	11·725	12·039	12·679
12	10·046	10·348	10·656	10·966	11·283	11·928
13	9·403	9·707	10·014	10·328	10·646	11·296
14	8·853	9·157	9·467	9·782	10·103	10·759
15	8·377	8·683	8·994	9·311	9·634	10·296
16	7·961	8·268	8·582	8·902	9·227	9·895
17	7·596	7·904	8·220	8·542	8·870	9·544
18	7·271	7·580	7·899	8·224	8·555	9·236
19	6·981	7·294	7·614	7·941	8·275	8 962
20	6·722	7·036	7·358	7·688	8·024	8·718
21	6·487	6·804	7·128	7·460	7·800	8·500
22	6·275	6·593	6·920	7·255	7·597	8·305
23	6·081	6·402	6·731	7·068	7·414	8·128
24	5·905	6·227	6·559	6·899	7·247	7·968
25	5·743	6·068	6·401	6·744	7·095	7·823
26	5·594	5·921	6·257	6·602	6·956	7·690
27	5·456	5·785	6·124	6·472	6·829	7·570
28	5·329	5·660	6·001	6·352	6·712	7·459
29	5·212	5·545	5·888	6·241	6·605	7·358
30	5·102	5·437	5·783	6·139	6·505	7·265

If a loan of 1 lakh repayable in 30 years were borrowed under this plan, the annual payment would at 6 per cent. amount to Rs. 7,265 or a total of Rs. 2,17,950 which is slightly less than under the former system.

None of these plans, however, are satisfactory in so far that a Municipality is suddenly relieved of a large annual payment; a much better plan would be to arrange that the amount payable decreased year by year; the Municipal income be thus gradually, instead of suddenly, relieved of a large annual payment. The steady progress of Municipal work would thus be better assured.

APPENDIX.

USEFUL NOTES ON SANITATION AND ENGINEERING.

SANITARY NOTES.

Disinfection.

Heat.—Heat of boiling water, 212°, will destroy all vitality in animal cells and molecules.

Clothes and bedding of patients suffering from infectious diseases may be safely used by healthy persons after exposure to 212° Fah. for one hour.

Fabrics begin to scorch at from 255° to 260° Fah.

Woollen fabrics change colour after exposure to six hours of 212° Fah. or two hours of 220° Fah.

Cotton and linen after six hours of 212° Fah. or after two hours of 220° Fah. show signs of change of colour, but the strength of the material is not diminished until after two hours at 300° Fah.

Bedding, blankets, carpets and such like, which cannot well be disinfected at home, must be disinfected by *steam* at low pressure, as recommended by Dr. Meyer. Where articles have been soiled with albuminous matter, the heat will cause coagulation and a permanent stain, unless the soiled parts have been previously washed in cold water.

If the bedding or other articles are very filthy or dilapidated, they should be destroyed by fire. Leather and letters should be exposed to dry heat only.

Liquids such as water and milk after being boiled (212° Fah.) will not carry disease.

The following are useful disinfectants:—

Sanitas fluid is an aqueous solution of peroxide of hydrogen with soluble camphor ($C_{10}H_{18}O_3$) and thymol, and is produced by the oxidation of turpentine in the presence of air and water. Sanitas oil remains when the fluid is removed, and contains various oxidized bodies and an organic (probably camphoric) peroxide, which gives off peroxide of hydrogen and camphoric acid to the air. Sanitas acts both as a disinfectant and an oxidant, and being non-poisonous by itself, it is the safest for general

use. By its power of rapid oxidation it stops putrefactive decomposition (Kingzett).

Chloride of lime is useful for excreta; if used for clothing, 2 ounces to a gallon is strong enough, stronger will destroy the materials.

Ferrous sulphate is a cheap deodarant, but, according to Koch, is not a disinfectant proper.

Carbolic acid has a powerful restraining effect upon the growth of bacteria, but as a disinfectant is very feeble even in vapour. Its compounds and solutions of it in alcohol or oil are less powerful than carbolic acid itself. Koch prefers it (5 per cent. solution) for disinfecting the excreta and soiled linen of cholera patients.

Permanganate of potash is a good deodarant and a true disinfectant to some extent, but its action is much weakened if the infective matter is mixed with a quantity of other organic matter. It is non-poisonous, but stains clothing, &c.

Disinfection of water in wells.—Cholera cases can often be traced to poisoning well water. The deposits of quicklime, alum, and permanganate of potash in wells are excellent and cheap disinfectants.

Rules for clearing rooms after infection.

(1) Remove all infected fabrics or clothing to be dealt with separately.

(2) Cleanse all wood work with soap and water to which one part of carbolic acid has been added to each three gallons of water.

(3) Close the room; fumigate for three hours with fumes of sulphurous acid using 1 lb. of sulphur to each 1,000 cubic feet of space. This is the usual quantity but gives a strength of only one per cent. which, Dr. Carpenter says, is inadequate; Letheby recommends ½ ounce for each ten cubic feet.

(4) Open the room and thoroughly ventilate for thirty-six hours.

(5) If the room has white-washed walls or ceilings, thoroughly scrape off the old wash and renew with wash to which some carbolic acid has been added. Other descriptions of wall surfaces should be washed with sanitas and water or a solution of corrosive sublimate (1 in 5,000).

Disinfection of fabrics and clothing.

The fabrics and clothing removed from the room to be boiled with soda, exposed to heat and fumigated with sulphur as already described; two handfuls of washing soda should be used to each

gallon of water. After boiling immerse in a carbolic acid solution of four *fluid ounces** of carbolic acid to 1 gallon of water. Soiled bandages, rags, &c., should be burnt.

Rules for the treatment of excrementitious matter in disease.

Matters discharged from the body should be received in a vessel containing half pint of one of the following disinfecting solutions :—

(1) A solution of 2 lb. of sulphate of iron to 1 gallon of water.
(2) A solution of 1 quart of chloride of zinc to 3 quarts of water.
(3) A solution of 1 lb. of sulphate of zinc to 1 gallon of water.
(4) A solution of 4 fluid ounces of carbolic acid to 1 gallon of water.

The Local Government Board (England) advise the use of the following solution for excreta, clothing, floors, &c. :—

½ ounce of corrosive sublimate.
1 ounce (fluid) of hydrochloric acid.
3 gallons of water.

Colour with permanganate of potash to prevent accident or with 5 grains of aniline blue.

For the daily ordinary excreta of an individual (4 ounces), one-half ounce of Calvert's and McDougall's powder will have a preservative effect for 18 to 20 days, one-quarter of an ounce for 3 or 4 days.

Common chemical terms and their scientific equivalents.

Common names.	Chemical names.
Aqua fortis	Nitric acid.
Aqua regia	Nitro-muriatic acid.
Blue vitriol	Sulphate of copper.
Calomel	Chloride of mercury.
Chalk	Carbonate of calcium.
Caustic potash	Hydrate potassium.
Common salt	Chloride of sodium.
Copperas or green vitriol ..	Sulphate of iron.
Corrosive sublimate	Bichloride of mercury.
Dry alum	Sulphate aluminum and potassium.
Fire-damp	Light carburetted hydrogen.
Galena	Sulphide of lead.

* 1 fluid ounce = $\frac{1}{20}$th part of a pint.

COMMON CHEMICAL TERMS AND THEIR SCIENTIFIC EQUIVALENTS —*cont.*

Common names.	Chemical names.
Iron pyrites	Bisulphide of iron.
Lime	Oxide of calcium.
Lunar caustic	Nitrate of silver.
Muriate of lime	Chloride of calcium.
Oil of vitriol	Sulphuric acid.
Potash	Oxide of potassium.
Red lead	Oxide of lead.
Rust of iron	Oxide of iron.
Salammoniac	Muriate of ammonia.
Slacked lime	Hydrate calcium.
Soda	Oxide of sodium.
Spirits of hartshorn	Ammonia.
Spirits of salt	Hydrochloride of muriatic acid.
Stucco or plaster of Paris	Sulphate of lime.
Sugar of lead	Acetate of lead.
Verdigris	Basic acetate of copper.
Vinegar	Acetic acid diluted.
Volatile alkali	Ammonia.
Water	Oxide of hydrogen.
White precipitate	Ammoniated mercury.
White vitriol	Sulphate of zinc.

ENGINEERING NOTES.

Strength and Weight of Materials.

Material.	Specific gravity.	Weight of cubic foot.	Tensile strength per square inch.
Metals.		LB.	TONS.
Copper, sheet	8·78	548·1	13·4
Do. wire	8·90	555·0	26·0
Iron, cast	7·23	451·0	7·3
Do. wrought	7·78	485·6	22·0
Steel	8·0	499·0	52·0
Lead, sheet	11·4	711·6	1·5
Tin	7·29	455·1	2·0
Zinc, cast	7·00	437·0	3·3
Brass, wire	8·54	533·1	22·0
Do. sheet	8·44	526·8	14·0
Do. cast	8·40	524·4	8·0
Timber.			LB.
Acacia	0·71	44	16,000
Box wood	1·28	80	20,000
Cedar	0·74	47	5,000

Strength and Weight of Materials—cont.

Material.	Specific gravity.	Weight of cubic foot.	Tensile strength per square inch.
Timber—cont.		LB.	LB.
Cork	0·24	15	...
Ebony	1·18	74	...
Jack wood	0·67	42	...
Mahogany	0·56	35	21,000
Oak	0·77	48	10,000
Pine, red	0·58	36	12,000
Do. yellow	0·50	32	...
Satin wood	0·96	60	...
Teak	0·74	46	8,000
Stones, &c.			Crushing strength per square inch.
Granite	2·62	165	10,900 to 6,300
Trap	2·72	170	...
Brick, common	1·6	100	...
Cement, Portland	1·7	105	600
Concrete, ordinary	1·9	119	...
Mortar	1·70	106	...
Sand, river	1·88	117	...
Tar	1·02	63	...

Weights of Materials, Wrought Iron.

Cubic inches × 0·28 = lb. avoirdupois.

Thickness of plate in inches × 40 = lb. per square foot.

Thickness of plate in eighths of inches × 5 = lb. per square foot.

Sectional area in inches × 3·34 = lb. per lineal foot.

Sectional area in inches × 10 = lb. per lineal yard.

Diameter of round iron in inches squared × 2·64 = lb. per lineal foot.

Weights of various metals, compared.

Weight of wrought iron × ·92 = weight of zinc.
× ·93 = do. of cast iron.
× 1·02 = do. of steel.
× 1·09 = do. of brass.
× 1·15 = do. of copper.
× 1·47 = do. of lead.

Weight of a Lineal foot of round and square Bar iron, in lb.

Diameter of side.	Square bars.	Round bars.
$\frac{1}{4}''$	0·209	0·164
$\frac{1}{2}''$	0·835	0·656
$\frac{3}{4}''$	1·879	1·476
$1''$	3·34	2·62
$1\frac{1}{4}''$	5·25	4·09
$1\frac{1}{2}''$	7·51	5·90
$1\frac{3}{4}''$	10·29	8·03
$2''$	13·36	10·49

Weight of a Lineal Foot of Bar iron, 1 inch thick.

Breadth.	lb. per foot.	Breadth.	lb. per foot.
1 inch	3·34	2 inches	6·68
$1\frac{1}{4}$ „	4·17	3 „	10·02
$1\frac{1}{2}$ „	5·00	5 „	16·70
$1\frac{3}{4}$ „	5·84	6 „	20·05

For other breadths multiply in proportion.

Weight of a square foot of Wrought Iron plates.

Thickness.	Weight.	Thickness.	Weight.
INCHES.	LB.	INCHES.	LB.
$\frac{1}{16}$	2·5	$\frac{5}{8}$	25·0
$\frac{1}{8}$	5·0	$1\frac{1}{16}$	27·5
$\frac{3}{16}$	7·5	$\frac{3}{4}$	30·0
$\frac{3}{8}$	15·0	$1\frac{3}{16}$	32·5
$\frac{7}{16}$	17·5	$\frac{7}{8}$	35·0
$\frac{1}{2}$	20·0	$1\frac{5}{16}$	37·5
$\frac{9}{16}$	22·5	1	40·0

Weight of Angle and T *Iron.*

Rule for calculating weight of ordinary angle and T iron.

W = Weight of angle iron per lineal foot.
B = Breadths of flanges added in decimal parts of a foot.
T = Thickness of angle iron in decimal parts of a foot.
w = Weight of iron in lb. per square foot of the thickness of the angle iron.

$$W = (B - T) \times w.$$

Weights of ⊔ (channel) and H iron may be found from the tables of angle and T iron in the following manner, provided the web and flanges are of the same mean thickness :—

Let the number in the side column of the tables referred to, equal half the sum of the depth of web, and breadth of both flanges ; then twice the weight corresponding thereto will be the weight per lineal foot according to the thickness of the channel or H iron required.

Weights of Angle and T Iron in lb. per lineal foot.

Breadths of flanges added (inches).	Thickness in fractions of an inch.								Breadths of flanges added (inches).
	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	
2	1·13	1·46	1·76	2·03	...	...	...	...	2
2 1/8	1·21	1·56	1·89	2·19	...	...	...	...	2 1/8
2 1/4	1·29	1·67	2·02	2·34	...	...	...	...	2 1/4
2 3/8	1·37	1·77	2·15	2·50	...	...	...	...	2 3/8
2 1/2	1·45	1·88	2·28	2·66	3·01	...	...	...	2 1/2
2 5/8	1·52	1·98	2·41	2·81	3·19	...	...	...	2 5/8
2 3/4	1·60	2·08	2·54	2·97	3·37	...	...	...	2 3/4
2 7/8	1·68	2·19	2·67	3·13	3·55	...	...	...	2 7/8
3	1·76	2·29	2·80	3·28	3·74	4·17	...	...	3
3 1/8	1·84	2·40	2·93	3·44	3·92	4·37	...	...	3 1/8
3 1/4	1·91	2·50	3·06	3·59	4·10	4·58	...	...	3 1/4
3 3/8	1·99	2·60	3·19	3·75	4·28	4·79	...	...	3 3/8
3 1/2	2·07	2·71	3·32	3·91	4·47	5·00	5·51	..	3 1/2
3 5/8	2·15	2·81	3·45	4·06	4·65	5·21	5·74	...	3 5/8
3 3/4	2·23	2·92	3·58	4·22	4·83	5·42	5·98	...	3 3/4
3 7/8	2·30	3·02	3·71	4·38	5·01	5·63	6·21	...	3 7/8
4	2·38	3·13	3·84	4·53	5·20	5·83	6·45	7·03	4

Weight of Nuts and Bolt Heads in lb.

Diameter of bolt in inches.	1/4	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2	1 3/4	2	2 1/4	3
Weight of hexagon nut and head.	·017	·057	·135	·261	·45	·72	1·07	2·09	3·61	5·7	8·56	17	23·8
Weight of square nut and head.	·021	·071	·169	·330	·57	·90	1·35	2·63	4·55	7·2	10·8	21	36·4

D = diameter of bolt in inches.
W = weight of nut and head in lb.
$W = 1{\cdot}07\ D^3$ for hexagon $= 1{\cdot}35\ D^3$ for square.

Angles of Roofs.

Proportion of rise to span.	Angle.		Slope.	Proportion of rise to span.	Angle.		Slope.
	DEG.	IN.			DEG.	IN.	
$\frac{1}{6}$ ...	18	25	3 to 1	$\frac{2}{3}$ ...	53	00	$\frac{3}{4}$ to 1
$\frac{1}{4}$ ...	26	35	2 to 1	$\frac{3}{4}$ ...	56	20	$\frac{2}{3}$ to 1
$\frac{1}{3}$ ...	33	42	$1\frac{1}{2}$ to 1	1 ...	63	30	$\frac{1}{2}$ to 1
$\frac{1}{2}$ ...	45	00	1 to 1	...	...		...

Load on roofs exclusive of framing.

	Per square of 100 supl. feet. CWT.	Minimum slope. DEG.
Lead covering weighs ..	7	4
Zinc	$1\frac{1}{2}$	4
Corrugated iron	3	4
Slates	$7\frac{1}{2}$ to 9	$25\frac{1}{2}$ to 30
Tiles	8 to 15	$26\frac{1}{2}$ to 30
Boarding, $\frac{3}{4}$ thick	$2\frac{1}{2}$	25
Boarding, $1\frac{1}{2}$ thick	5	..
Timber framing for slated or tiled roofs	5 to 6	..
Additional load for pressure of wind	36	..
Steepest angle of Gothic roofs. ..		60

Pressure of wind on roofs (Unwin).

a = Angle of surface of roof with direction of wind.
F = Force of wind in lb. per square foot.
A = Pressure normal to surface of roof = F. sin. a 1·84 cos. a—1.
B = Pressure perpendicular to direction of wind = F. cot. a sin. a 1·84 cos. a.
C = Pressure parallel to direction of wind = F. sin. a 1·84 cos. a.

Angle of roof = a.	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
A = F ×	·125	·24	·45	·66	·83	·95	1·00	1·02	1·01	1·00
B = F ×	·122	·24	·42	·57	·64	·61	·50	·35	·17	·00
C = F ×	·01	·04	·15	·33	·53	·73	·85	·96	·99	1·00

Birmingham and Imperial Standard Wire Gauges.

These are well-known gauges which are used in measuring the thickness of sheet metals, diameter of wire, &c. The equivalent inches are as follows :—

Birmingham wire gauge.		Imperial standard wire gauge.	
Size.	Inches.	Size.	Inches.
...	...	7/0	·500
...	...	6/0	·464
...	...	5/0	·432
0000	·454	4/0	·400
000	·425	3/0	·372
00	·380	2/0	·348
0	·340	1/0	·324
1	·300	1	·300
2	·284	2	·276
3	·259	3	·252
4	·238	4	·232
5	·220	5	·212
6	·203	6	·192
7	·180	7	·176
8	·165	8	·160
9	·148	9	·144
10	·134	10	·128
11	·120	11	·116
12	·109	12	·104
13	·095	13	·092
14	·083	14	·080
15	·072	15	·072
16	·065	16	·064
17	·058	17	·056
18	·049	18	·048
19	·042	19	·040
20	·035	20	·036
21	·032	...	...
22	·028	...	...
23	·025	...	...
24	·022	...	...

Safe load on chains.

D = diameter in eighths of an inch.
W = safe load in tons.

$$D = \sqrt{9W}$$

$$W = \frac{D^2}{9} = 7{\cdot}111\ d,^2$$ where d = diameter of iron in inches.

Table of working Load (Tons) of chains.

Diameter in inches ...	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Load	·44	·70	1·0	1·36	1·78	2·25	2·78	3·36	4·0
Diameter in inches ...	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	$1\frac{3}{4}$
Load	4·69	5·44	6·25	7·11	9·0	11·11	13·44	16·0	21·78

Safe working loads for Hemp Ropes.

Circumference of rope.	Safe working load.		
	TONS.	CWT.	QRS.
1 inch	0	1	3
2 inches	0	7	0
3 „	0	16	0
4 „	1	8	2
5 „	2	4	2
6 „	3	4	0

Average Evaporative Power of Fuel.

——	lbs. of water evaporated.	Relative values.	Relative amounts.
1 lb. of coke	9	1	1
„ coal	9	1	1
„ slack	4	·44	2·25
„ oak, dry	$4\frac{1}{2}$	0·50	2
„ pine	$2\frac{1}{2}$	0·27	4
„ casuarina, dry	$2\frac{1}{2}$	0·27	4
„ do. green	$1\frac{1}{2}$	0·17	6

CENTRIFUGAL PUMPS.

Table of deliveries with approximate horse powers.

Bore of pump and diameter of suction and Discharge pipes.	4″	5″	6″	7″	8″	9″	10″	12″
Gallons of water discharged per minute.	200 to 300	350 to 500	500 to 750	700 to 1,000	900 to 1,300	1,150 to 1,600	1,600 to 2,200	2,000 to 3,000
Approximate Nominal H. P. required for each foot of Lift.	·08	·15	·25	·30	·35	·45	·65	·90

Bore of pump and diameter of suction and Discharge pipes.	14″	15″	16″	18″	20″	22″	24″
Gallons of water discharged per minute.	2,800 to 4,000	3,000 to 5,500	3,500 to 5,300	4,500 to 6,600	6,000 to 8,200	7,000 to 10,000	8,500 to 12,000
Approximate Nominal H. P. required for each foot of Lift.	1·2	1·3	1·5	1·8	2	3	3

NOTE.—The powers above given are for discharging the minimum quantities when working average lifts.

Useful Memoranda for Hydraulic Calculations.

		LB.	
1 cubic foot of water	=	62·425	= ·028 tons.
1 cubic inch	=	0·03612	
1 gallon	=	10 lb.	= 0·16 c. ft.
1 cubic foot	=	6·24 gallons (say $6\frac{1}{4}$).	
1 cwt. of water	=	1·8 cft.	= 11·2 gallons.
1 ton of water	=	35·9 cft.	= 224 gallons.

If P = pressure in lb. per square inch and H = head of water in feet, then $P = H \times ·4335$ and $H = P \times 2·307$.

Pressure per square foot = H × 62·4.
1 cubic foot of sea water = 64·11 lb.

Weight of sea water as compared with fresh water is as 1·027 to 1.

Rainfall and Evaporation.

Inches of rainfall × 2,323,200 = cubic feet per square mile.
Do. × 14½ = millions of gallons per square mile.
Do. × 3,630 = cubic feet per acre.
Average fall in India on plains .. 50 to 70 inches.
Do. on hills .. 130 to 190 ,,
Greatest evaporation in India in 24 hours .. ·56 inches.
Average do. do. do. .. ·22 ,,

Contents of a reservoir = approximately surface area × ⅔ greatest depth.

Natural slopes of Earths (with Horizontal Line).

	DEG.		DEG.
Gravel, average ..	40	Shingle	39
Dry sand	38	Rubble	45
Sand	22	Clay, well drained ..	45
Vegetable earth ..	28	Clay, wet	16
Compact earth	50		

Proportions of Mortar, Cement, &c.

Mortar or chunam 1 lime to 2 or 3 of sharp river sand.
Concrete ,, 1 lime, 4 gravel, 2 sand.
Cement ,, 1 sand, 1 cement or 1 sand, 3 cement.

Plastering.

12 lb. whiting, ½lb. blue black, 1¾ gallons of size are required for 100 yards superficial 'once' done; 21 lb. of whiting, ¾ lb. blue black, 2¾ gallons of size if 'twice' done.

Thickness of compo :	½ in.	¾ in.	1 in.
1 bushel of cement will cover	2¼ yds.	1½ yds.	1⅐ yds.
1 Do. do. and 1 of sand	4½ ,,	3 ,,	2¼ ,,
1 Do. do. and 2 of sand	6¾ ,,	4½ ,,	3⅓ ,,
1 Do. do. and 3 of sand	9 ,,	6 ,,	4½ ,,

¾ inch is the usual thickness.

1 cubic yard of chalk lime, 2 yards of road drift or sand, and 3 bushels of hair will cover 75 yards sup. render and set on brick, or 70 yards on lath.

Floated work will require about the same as 2 coats and set.

1 cask of Portland cement holds about 4 cubic feet.

Asphalte Flooring.

1 inch thick requires per superficial feet $12\frac{1}{2}$ lb. asphalte.
$\frac{3}{4}$ Do. do. $9\frac{3}{8}$ do.
$\frac{1}{2}$ Do. do. $6\frac{1}{4}$ do.

PLUMBING.

The Thickness of Lead.

Weight in lb. per foot superficial.	Thickness in inches.	Weight in lb. per foot superficial.	Thickness in inches.
1	0·017	7	0·118
2	0·034	8	0·135
3	0·051	9	0·152
4	0·068	10	0·169
5	0·085	11	0·186
6	0·101	12	0·203

The weights recommended are as follows :—

Roofs, flats, and main gutters	7 lb. lead.
Hips, ridges and small gutters	6 ,,
Flashings	5 ,,
Cisterns and sinks, bottoms	7 ,,
Cisterns and sinks, sides	6 ,,
Soil pipes	8 ,,

Lead pipes—weight per foot run = 3·8834 D^2—D'^2, D and D′ being the external and internal diameter in inches.

Painting.

1 gallon of mixture or 6 pints of raw linseed oil, 1 pint boiled oil, 1 pint of turpentine, requires from 12 to 14 lb. of dry paint. These proportions vary according to circumstances.

A gallon will cover—	SQUARES.
on stone or bricks about	2·25 to 2·70
on wood	4·50 to 6·30
on well-painted surface or iron	7·20
one gallon of tar, first coat	1·08
do. do. second coat	1·44

WEIGHTS AND MEASURES.

Southern India.

——		——		lb.	oz.	drms.
180 grains	=	1 tola	=	0	0	6·58
30 tolas	=	1 pollum	=	0	1	3·75
40 pollums	=	1 viss	=	3	1	5·94
8 viss	=	1 maund	=	24	10	15·00
1 candy	=	20 maunds	=	500	0	0
1 Mysore candy			=	560	0	0

Avoirdupois Weight.

——		——		French Grammes.
16 drams.	=	1 oz.	=	28·35
16 oz.	=	1 lb.	=	453·59
28 lb.	=	1 qr.	=	12,700
4 qr.	=	1 cwt.	=	50,802
20 cwt.	=	1 ton	=	1,016,048

Troy Weight.

——		——		French Grammes.
24 grains	=	1 dwt.	=	1·55
20 dwt.	=	1 oz.	=	31·10
12 oz.	=	1 lb.	=	373·242
175 lb. troy	=	144 lb. avoirdupois.		
lb. avoirdupois	×	·82286	=	lb. troy.
lb. troy	×	1·2153	=	lb. avoirdupois.

Long Measure.

——		——		Metres.
12 inches	=	1 foot	=	·0254
3 feet	=	1 yard	=	·9144
220 yards	=	1 furlong	=	201·16
8 furlongs	=	1 mile	=	1609·315

Square Measure.

				Square Metres.
144	square inches	=	1 square foot =	·0929
9	square feet	=	1 square yard =	·8361
30¼	square yards	=	1 perch =	25·292
40	perches	=	1 rood =	1011·7
4	roods	=	1 acre =	4046·7
10	square chains	=	1 acre	
1	square mile	=	640 acres.	
1	acre	=	43,560 square feet	

South Indian Measures.

1 ground	=	2,400 square feet.
24 grounds	=	1 cawnie = 57,600 square feet.
1 cawnie	=	1·322 acres.

Surveying Measure.

100 links	=	1 chain.
1 chain	=	66 feet.
10 chains	=	1 furlong.
1 mile	=	5,280 feet.

Measures of Capacity.

1 gallon = ·16 cubic feet = 10 lb.
Cubic feet × 6·2425 = gallons.
1 bushel = 2218·19 cubic inch = 1·28 cubic feet.
Cubic feet × ·78 = 1 bushel.
1 parah = 4,000 cubic inches (South India).

METRICAL SYSTEM COMPARED WITH ENGLISH MEASURES.

Long Measure.

	Metres.	Feet.
Millimetre	·001	·00328
Centimetre	·01	·03280
Decimetre	·10	·32809
Metre	1·00	3·2809
Decametre	10·0	32·809
Hectometre	100	328·09
Kilometre	1000	3280·9

Solid Measure.

——	Cubic Metre.	Cubic Inches.
Millistre	·001	61·028
Centistere	·01	610·28
Decistere	·1	6102·8
Stere	1	61028·0
		Cubic yards.
Decastere	10	13·08
Hectostere	10·0	130·802

Weights.

——	Grammes.	Avoirdupois, ounces.	Avoirdupois, lb.
Milligramme	·001	...	...
Centigramme	·01	...	...
Decigramme	·1	...	...
Gramme	1	·035	·0022
Decagramme	10	·35	·022
Hectrogramme	100	3·527	·22046
Kilogramme	1000	35·2739	2·2046

Dry and Fluid Measure.

——	Litre.	Inches.	Feet.	Gallons.
Millitre	·001	·061	...	·00022
Centilitre	·01	·61	...	·0022
Decilitre	·1	6·1	...	·022
Litre	1·0	61·02	·0353	·22
Decalitre	10	610·28	·353	2·2
Hectolitre	100	...	3·53	22
Kilolitre	1000	...	35·317	220

NOTE.—A litre = a cubic decimetre.
A kilolitre = a cubic metre.

Mensuration of Surfaces.

Area of a triangle = base × ½ perpendicular.
Do. circle = diameter^2 × ·7854.
Sector of circle = length of arc × ½ radius.

Mensuration of Solids.

Cylinder = area of one end × length.
Sphere = diameter^3 × ·5236.
Cone or pyramid = area of base × ⅓ the perpendicular height.
Wedge = area of base × ½ the perpendicular height.

Timber Measuring.

G = ¼ girth of tree or log at middle in feet.
g = ¼ do. do. end do.
g^1 = ¼ do. do. other end in feet.
L = length of log in feet.
C = cubic contents of log in feet.

$$C = L \frac{(G+g+g^1)^2}{3}$$

Casks.

D, d = inside diameters at heads in inches.
M = do. at the bung in inches.
L = length in inches.

The capacity in Imperial gallons = ·0014162 L (D d + M^2).

Properties of the Circle.

Diameter × 3·14159 = circumference.
Diameter × ·886226 = side of a square of equal area.
Diameter^2 × ·7854 = area of circle.
Radius × 6·28318 = circumference.
Circumference × ·31831 = diameter.
Circumference = 3·5449 $\sqrt{\text{area of circle}}$.
Diameter = 1·1183 $\sqrt{\text{area of circle}}$.
Degrees in arc whose length = radius = 57·2958°

GLOSSARY OF SANITARY, ENGINEERING AND INDIAN TERMS.

A

Abscissa.—One of the elements of reference by which a point of a curve is referred to a system of fixed rectilineal co-ordinate axes.

Acetate.—Any salt formed by the union of acetic acid with a salifiable base.

Acid.—A substance having the properties of combining with alkalies and alkaline oxides and of reddening most blue vegetable colours and usually of a strong sharp taste.

Aggregate.—A mass composed of a mixture of stone and gravel or sand, &c.

Air valve.—A valve to allow the exit of air from pipes.

Albumen.—A substance existing nearly pure in the white of an egg and its chief component.

Algae.—A division of cryptogramic plants.

Alkali.—One of a class of caustic bases which is soluble in water or alcohol, unites with oil and fats to form soaps, neutralises and changes reddened litmus to blue.

Ammonia.—A volatile alkali.

Anemometer.—An instrument with which the velocity of currents of air is measured.

Anicut.—A weir or dam across a river or stream.

Artesian wells.—Springs obtained by boring through impermeable strata into lower strata which contain water.

Ashlar.—Stone dressed and cut to definite sizes.

Asphalte.—A substance derived from bituminous limestone.

B

Bacilli.—Rod shaped pathogenic micro-organisms to which the term 'bacteria' was originally applied.

Bacteria.—A generic term including all pathogenic micro-organisms.

Ballapum.—Soap stone; steatite.

Beds.—The horizontal courses of a wall; the undersides of any particular stones.

Bengal roof.—A sloping terraced roof.

Bibulous.—The character of a porous absorbent body.

Bifurcate.—To divide into two branches.

BIGGAH.—A land measure; the third part of an acre.
BIND, TO.—To cement together.
BOND.—The method of building in which all portions of a wall are tied together.
BRANCH.—A term applied to a pipe having another issuing from it; a T pipe.
BRAND.—A mark; a trade mark.
BRATTIES.—Cakes made from cowdung and straw, for fuel.
BRIQUETTE.—A small brick; a term usually applied to test bricks.
BUSHEL.—A dry measure containing 8 gallons or 1·28 cubic feet.
BUSTEE.—A native village (in Bengal); a parcherry (in Madras) where persons of the lower castes live; a collection of huts.
B.W.G.—Birmingham wire gauge (see appendix).

C

CALINGULAH.—The surplus weir of a tank.
CARBOLIC ACID.—A substance obtained by the distillation of coal-tar and used as a disinfectant—phenol.
CARBON.—An elementary substance forming the base of charcoal.
CARBONIC ACID.— An acid containing one part of carbon and two parts of oxygen.
CARBONATE.—A salt formed by the union of carbonic acid with a base.
CARBONIC.—Pertaining to carbon.
CARBONIZATION.—Act of converting into carbon.
CARBURETTED.—The characteristic of a body containing carbon and hydrogen.
CARRIER.—A term applied to the distributing drains in sewage farms.
CENTIGRADE SCALE.—A thermometric scale in which the freezing point is 0° and the boiling point 100°.
CHLORATE.—A salt formed by the union of chloric acid with a base.
CHLORIDE.—A compound of chlorine with another element.
CHLORINE.—A constituent of common salt.
CHUNAM.—Lime made from shells; mortar made with such lime.
CHUNAM BORDERS.—Strips of mortar laid over roofs to keep the tiles in place.
CLEAT.—A piece of wood to belay ropes to.
COCK.—A plug valve.
COLLAR.—A sleeve; a short piece of pipe passed over the spigot ends of two other pipes to form a joint.
COMPOUND.—The land attached to a dwelling house.
CONCRETE.—An artificial mixture of stone and mortar.
CONDUIT.—An artificial passage for the flow of water; a large pipe usually of masonry, a canal, &c.

CONGLOMERATE.—A term applied to a natural stone consisting of debris connected together by some cementing material.
COOLIE.—A labourer.
CORRUGATED IRON.—Iron rolled so as to present in section ridges and valleys.
COURSE.—A layer of bricks or stones in a building.
CROWN.—The highest portion of an arch.
CUDDAPAH STONES OR SLABS.—A slate stone found in the Cuddapah District.

D

DEAD END.—The end of a pipe unconnected with any other pipe.
DEODORIZATION.—Depriving of odour from impurities.
DERRICK.—A mast supported by guys ; a crane.
DHOBIE.—A washerman.
DISCHARGE COCK.—A cock or valve at the end of a pipe.
DISTILLATION.—The process by which the volatile portion of a body is separated and condensed.
DRAIN.—A small sewer, a channel.
DROWNED WEIR.—A weir at which the level of the water which has passed the weir remains above the level of the top of the weir.

E

ENDEMIC.—Peculiar to a district or people and always present.
ENDOGENOUS.—Increasing by internal growth and elongation at summit.
ENTERIC FEVER.—A specific zymotic fever.
ENTOZOA.—Intestinal worms.
ENTOZOIC.—A term given to diseases produced by entozoa.
EPIDEMIC.—Affecting a whole community or many people at one time, a disease which appears at intervals as opposed to one which is endemic or always present.
EURASIAN.—A half-caste or person with mixed European and Indian blood.
EXOGENOUS.—Growing by addition to the outside of the wood.

F

FARENHEIT SCALE.—A thermometric scale in which the boiling point is 212° and the freezing point 32°.
FAUCET.—That portion of a pipe into which an adjoining pipe is entered.
FIRECLAY.—A kind of clay, chiefly pure silicate of alumina, capable of sustaining great heat.
FIRECOCK.—A cock to which a hose can be affixed in order to obtain water in case of fire, &c. ; a hydrant.
FLANGED.—Having a projecting rim for attachment to something else.

FOOTINGS.—Steppings; the widening out of a wall at the foundation.

FERROCYANIDE.—A compound of ferrocyanic acid and a base.

G

GABLE.—The triangular portion of an exterior wall of a building above the level of the top of the side walls and below the slopes of the roof.

GALVANIZED.—Coated with zinc.

GAUGE.—A fixed measure; a frame giving the sectional outline of a portion of a structure or mass of materials.

GHEE.—Clarified butter.

GRADIENT.—A regular slope; the degree of slope.

GRAMME.—See page 546.

GRAVITY.—Weight; the result of the attraction of the earth.

GRAVITY, SPECIFIC.—The relative weight of a body as compared with that of an equal volume of water.

GRAVITATION.—The action exercised by the power of gravity.

GRID.—A grating.

GUANO.—Excrement of sea-fowls.

GULLY.—A pit for arresting solid matter and preventing it entering sewers; a cess pit.

GULLIE.—A narrow lane.

GUTTER.—A side drain.

H

HALLALCORE.—Nightmen or scavengers of Bombay.

HEAD.—The pressure at any particular point in a closed conduit.

HIP ROOF.—A roof formed by equally inclined planes at the ends and sides.

HOGSHEAD.—52½ imperial gallons; half-a-pipe.

H. P.—Horse-power; a term used in connection with engines and machines as showing their powers in relation to the work of a horse. One horse-power is supposed to be equal to 33,000 lb. raised one foot in one minute (*vide* pages 324 and 325).

HYDRAULICS.—The science relating to fluids in motion.

HYDRAULIC MEAN DEPTH.—See page 270.

HYDRANT.—A water plug; a firecock.

HYGIENE.—The science of health.

I

INCINERATION.—To reduce to ashes.

INVERT.—An inverted arch in a position such as the floor of a culvert, &c.

IODIDE.—The chemical combination of iodine and oxygen.

IODINE.—A simple chemical body found mostly in combination with potassium and soda.

J

Jelly.—Broken stones, bricks, &c.

L

Lamp-hole.—An inspection shaft over sewers down which a lamp may be lowered.
Laterite.—A ferruginous conglomerate.
Leep.—To plaster with clay and cowdung.
Litmus.—A colouring matter prepared from lichens.
Litmus paper.—An unsized paper prepared with litmus for use as a chemical test. Blue litmus paper turns red with an acid. Red litmus paper blue with an alkali.
Litre.—See page 546.
Logarithm.—One of a series of numbers increasing in arithmetical progression representing a series increasing in geometrical progression and used to facilitate mathematical calculations.
Lucerne.—A grass used for fodder.
Lymph.—The watery part of the puss or virus used in vaccination.

M

Manhole.—A shaft for entry to a sewer and for ventilation.
Mehter.—A sweeper; a scavenger.
Meshes.—The spaces between the threads in a net or wires in a screen.
Meter.—An instrument for measuring the quantity of fluid or gas passing through it.
Millegramme.—See page 546.
Mofussil.—Outside the Presidency town; the country contrasted with the town.
Mussuck.—A bag formed from a whole sheep's or goat's skin in which the Mahomedan water-carrier carries water.

N

Nalla or Nulla.—A stream or creek.
Needle.—A beam inserted through a wall to support a portion of it.
Nitric acid.—An acid composed of nitrogen and oxygen (*vide* page 20).
Nitrite.—A salt formed by the combination of nitric acid with a salifiable base.
Nitrates.—Formed from nitrites by exposing the former to a high temperature and expelling a portion of the oxygen of the nitric acid.
Nitrogen.—A gaseous element without taste, odour or colour and forming four-fifths of common air.

NITROGENOUS—Containing nitrogen.
NOZZLE.—A contracted orifice at the end of a pipe or hose.

O

OPHTHALMIA.—Inflammation of the membranes of the eye.
ORDINATE.—The distance of any point in a curve measured on a line called the axis of ordinates from another line called the axis of abscissas.
OUTFALL.—The point where sewers empty themselves ; the end of a sewer.
OXIDIZE.—The process by which metals are converted into oxides by combination with oxygen.
OXYGEN.—An elementary body forming, as a gas, 21 per cent. by volume of the atmosphere.

P

PADDY.—The rice-plant, rice before being husked.
PARAH.—A measure containing 4,000 cubic inches.
PARCHERRY.—A bustee ; a collection of huts.
PARIAH.—An out-caste ; the lowest caste among the Hindus.
PENT-ROOF.—See page 203.
PEON.—A messenger ; an office porter ; a gangsman over coolies.
PHOSPHURETTED.—Combined with phosphorus.
PIPES, SOCKET.—Ordinary plain pipes.
PIPES, TURNED AND BORED.—Pipes having the spigot end turned and the socket or faucet end bored.
POLING BOARD.—Boards used in fixing the levels of the intermediate points on lines of works.
POTASSIUM.—A soft bluish white lustrous metal having a strong affinity for oxygen.
POUDRETTE.—A fertilizing mixture made from excreta dried and mixed with earth, lime, &c.
PUCKA.—Well built ; built with bricks and mortar.
PUG MILL.—A mill for preparing clay for brick making.

R

RADIATE.—To proceed in lines diverging from a centre.
RADIUS.—The line drawn from the centre of a circle to any point on the circumference.
REAMUR.—A thermometric scale in which the freezing point is marked 0^{c} and the boling point 80^{0}.
RETAINING WALL.—A wall which supports a mass of earth or water.
RUBBLE.—Stones of uneven size and shape used in undressed masonry.
RYOT.—A peasant ; a cultivator ; a tenant.

S

Saddle.—See plate facing page 362.
Sag.—To bend ; to arch downwards.
Scantling.—A piece of timber cut to a small size, such as rafters, purlins, &c.
Service pipe.—A pipe set apart for the use of a particular house or block of houses.
Sewer.—A main drain.
Shastras.—The books of the Hindu sacred law.
Silica.—One of the primitive earths, occurring nearly pure in flint, rock crystal, quartz, &c.
Silicon.—The base of Silica.
Sluice valve.—A valve to regulate the supply through a pipe or stop it.
Soap-stone.—Steatite ; a mineral of the magnesium family.
Socket.—That portion of a pipe into which the spigot of another pipe is inserted.
Socket pipe.—A pipe with a plain socket not bored.
Soorki } .—Bricks pounded into powder.
Soorkee }
Span.—The horizontal distance from one support to another.
Spigot.—That portion of a pipe which enters the faucet or socket portion of an adjoining one.
Steining.—The brick-lining of a well or shaft.
Stoneware.—Potter's ware of a coarse kind glazed and burned.
Strata.—The various layers of matter forming the crust of the earth.
Strut.—A piece of timber, iron, steel, &c., in compression.
Sulphate.—A salt formed by sulphuric acid in combination with any base.
Sulphuretted.—Having sulphur in combination.
Sulphurous.—Containing sulphur.
Syphon.—A bent tube for drawing off liquids from one vesse or partition to another.

T

Tank.—A reservoir or artificial lake of any size.
Tap.—A discharge cock.
Taper.—A pipe of less diameter at one end than the other.
Taps and dies.—Tools used in screw cutting.
Tee.—A rectangular branch pipe.
Template.—A plate of wood or iron cut to the cross section of a moulding, or other feature of a work.
Terraced.—A term applied to flat roofs formed with layers of bricks and concrete.
Texture.—The disposition of the fibres of a body.
Trap (Rock).—A basaltic rock. The name trap is given on account of the stair-like appearance of the strata when exposed, from *trappa* (Saxon) a stair.

Trap.—A contrivance used for preventing gas from passing from one sewer to another, or from a sewer into a house or the open air.

Trellis work.—Net work ; lattice work.

Truss.—A framed structure used in supporting roofs.

Tubercle.—The deposit which accompanies scrofula or phthisis.

Turned and bored pipes.—Pipes which have their spigot ends turned and the inside of their faucet ends bored so as to fit accurately when put together ; in contradistinction to socket pipes which are pipes with plain joints requiring to be fixed with lead.

Typhoid fever.—A zymotic fever.

Tyre.—Curds.

U

Underpinning.—Building under existing work.

W

Water meter.—An instrument for measuring the consumption of water.

Weir.—A calingulah or anicut ; a wall over which water escapes.

Wire gauge.—A standard by which the thickness of wire is measured.

Z

Zymotic.—The name of a class of diseases pertaining to, or propagated by, fermentation, such as cholera, typhus, typhoid.

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